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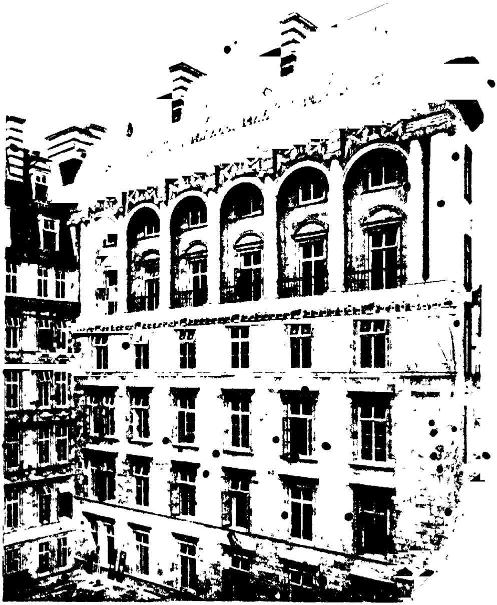

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*A RUDIMENTARY TREATISE*

ON THE MANUFACTURE OF

# BRICKS AND TILES.

BY

EDWARD DOBSON

AUTHOR OF "THE ART OF BUILDING," "MASONRY AND STONE-CUTTING,"
"FOUNDATIONS AND CONCRETE WORK," ETC., ETC.

TWELFTH EDITION

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# PREFACE TO THE TWELFTH EDITION

THE manufacture of bricks was for many centuries regarded as degrading, but the great part now played by bricks and tiles in modern domestic and public architecture has led to such interest and skill being taken in their manufacture, that it has now reached a pitch of perfection never before attained. Thus, there are many persons to whom a general knowledge of the principal methods of brickmaking is very useful, but who do not wish to enter into a deep study of the scientific principles underlying this industry, nor even to learn the multiplicity of precautions which must be taken to ensure success in actual manufacture. Students of architecture, builders, and estate owners are all likely to be interested in the "Art of Brickmaking" whilst caring little for its "science."

Hence the chief object of Mr. Dobson, as stated in the preface to the first edition of this work, has been maintained, and all that is attempted in the following pages is "to give a clear description of the actual manufacture of bricks and tiles, and to explain the leading differences which exist in the manner of conducting the several operations of Brickmaking in various parts of this country." For this reason, the characteristics of many clays and such subjects as "Plasticity," "Refractoriness," etc., and many minor processes of manufacture, have been treated very briefly. Although they are of the highest importance to the actual manufacturer, they are extremely difficult to study, and the inclusion of a fuller consideration of them would deprive the present work of the simplicity, practicality, and freedom from scientific technicalities so characteristic of its earlier editions, and would destroy its value to those for whom it is primarily intended.

Whilst retaining these features as far as possible in the present edition, so much progress has been made in the brickmaking industry as a whole, that considerable rearrangement of the information has been necessary. Several chapters have been re-written, some new ones have been added, and a large amount of matter which had become out of date has been thoroughly revised, so that the work is, to all intents and purposes a new one, based on the plan of the original.

The "geographical arrangement" which was a characteristic feature of the earlier editions, has been retained, though the introduction of machinery into almost every part of the country has made this arrangement of more historical than practical interest; an adequate geographical arrangement being impossible within the compass of a small volume.

Various matters of interest which were previously relegated to footnotes and appendices have now taken their rightful place in the text, so that each chapter is practically complete in itself.

Within the limits of a "Rudimentary Treatise" it is always difficult to write descriptions of operations and machinery which shall satisfy every reader. This is particularly so in connection with the subject of Clay-working. The reviser trusts, however, that such omissions as may occur will be found to be unimportant to those readers for whom this "outline" is specially written; but he will feel obliged if readers will kindly point them out to him at the address given below.

Readers requiring more information should consult more advanced treatises, to which the present one may be said to form an introduction. A short list of books, in which are given detailed descriptions and comparisons of machinery and processes which would be out of place here, will be found on p. 266 of the present volume.

ALFRED B. SEARLE.

THE WHITE BUILDING,
SHEFFIELD.

# ACKNOWLEDGMENTS

IN the First Edition of this work the Author acknowledged his indebtedness to numerous gentlemen for valuable assistance. Amongst others he selected for special mention the names of Mr. Arthur Aikin; Mr. John Lees Brown, of Lichfield; Mr. William Booker, of Nottingham; Mr. Richard Prosser, of Birmingham; Mr. Frederick Ransome, of Ipswich; Mr. Adams; Mr. Randall, of the Maiden Lane Tileries; and Mr. Samuel Pocock, of the Caledonian Fields, Islington.

The work was revised by Prof. Tomlinson, assisted by Mr. Robert Mallet, in 1863, and a chapter on making bricks by machinery, together with a considerable Appendix (now incorporated in the general text), were added.

For facilities afforded to him in the matter of new illustrations, the reviser of the present edition is indebted to a number of makers of brick machinery, etc.; their names will be found in the text, illustrations, and index. For assistance in revising the details of costs of manufacture, he is equally indebted to a number of his clients and friends who have permitted him to make use of the cost sheets at their yards in arriving at the figures stated.

# RUDIMENTS

OF THE

# ART OF MAKING BRICKS AND TILES.

## CHAPTER I.

### A BRIEF HISTORY OF BRICKMAKING.

It is unnecessary, in a little volume like the present, to enter at any length upon the early history of the Art of Brickmaking, nor would such an investigation, however interesting from a historical point of view, add much to our practical knowledge of the subject. It is, however, desirable to give a few particulars relative to the progress of the manufacture of bricks in this country, together with a brief sketch of the legal restrictions which have been imposed upon the operations of the brickmaker from time to time.

The use of bricks (both burned and unburned) as a building material, dates from a very early period. Burned brick is recorded in the Bible to have been used in the erection of the tower of Babel; and there is the testimony of Herodotus for the fact, which is confirmed by the investigations of travellers, that burned bricks, made from the clay thrown out of the trench surrounding the city, were used in building the walls of the city of Babylon. These very ancient bricks were of three kinds; one of which was very similar to the modern white Suffolk bricks, and another to the ordinary red hand-made brick of the present day.

Sun-dried bricks were extensively used in ancient times, especially in Egypt, where their manufacture formed the principal occupation of the Israelites during their bondage in Egypt after the death of Joseph. Very interesting ancient representations of the processes employed are still in existence, and throw much light on various passages of Scripture. Thus, the passage in Psalm lxxxi. 6, "I removed his shoulder from the burden; his hands were delivered from the (*water*) pots," is strikingly illustrated by pictures still preserved to us, in which labourers are carrying the tempered clay on their shoulders to the moulders, whilst others are engaged in carrying vessels of water to temper the clay.

The Egyptian sun-dried bricks were made with clay mixed with chopped straw, which was furnished to the Israelites by their Egyptian taskmasters before the application of Moses to Pharaoh on their behalf, after which the obligation was laid on them to provide their own straw. This was a grievous addition to their labour, as in the absence of straw a much larger number of bricks would crack and fall to pieces during drying, so that in order to produce the complete "tale" of bricks many more would have to be made than when straw was used. It would appear from the details given, that the Israelites worked in gangs, under the superintendence of an overseer of their own nation, who was provided with all necessary tools and materials, and who was personally responsible for the labour of the gangs.

Burned bricks were also used in Egypt for river-walls and hydraulic works, but, probably, not to any very great extent.

It is recorded in 2 Samuel xii. 31, that David made the children of Ammon pass through the brick-kiln.

The Romans used bricks, both burned and unburned, in great profusion; all the great existing ruins at Rome being of brick. At the decline of the Roman Empire, the art of brickmaking fell into disuse, but was revived in Italy after the lapse of several centuries. The mediæval ecclesiastical and palatial architecture of Italy exhibits many fine specimens of brickwork and ornamental work in terra-cotta; cornices and other decorations of great beauty being executed in the latter material.

In Holland and the Netherlands, the scarcity of stone led, at an early period, to the extensive use of bricks, both for domestic and ecclesiastical buildings, and these countries abound in fine specimens of brickwork, often in two colours combined with great taste, and producing a very rich effect, as in the celebrated examples at Leeuwarden in Friesland. It is worthy of remark, that in the fens of Lincolnshire and Norfolk, where it would naturally be expected that the same material would be used, the churches—many of which are exceedingly fine specimens of architecture—are built of small stones, said to have been brought from great distances on pack-horses.

Brickmaking appears to have been introduced into England by the Romans, who used large thin bricks or wall-tiles as bond to their rubble constructions; and such wall-tiles continued to be used in England until rubble work was superseded by regular masonry, about the time of the Norman Conquest. Bricks do not appear to have come into general use as a building material until long afterwards.

In the reign of Henry VIII., however, the art of brickmaking had arrived at such perfection that the remains of many buildings erected about this time exhibit some of the finest known specimens of ornamental brickwork.

The following is a list of some of the principal brick buildings erected at this period:—

| NAME. | WHEN BUILT. |
|---|---|
| Hurstmonceaux Castle, Sussex | Early in the reign of Henry VI. |
| Gate of the Ryehouse in Hertfordshire | Ditto. |
| Tattershall Castle, Lincolnshire | A.D. 1440. |
| Lollard's Tower, Lambeth Palace | A.D. 1454. |
| Oxborough Hall, Norfolk | About A.D. 1482. |
| Gateway, Rectory, Hadleigh, Suffolk | Close of 15th century. |
| Old part of Hampton Court | A.D. 1514. |
| Hengrave Hall, Suffolk | Finished A.D. 1538. |
| Manor House, East Barsham, Norfolk | During the reign of Henry VII. |
| Thorpland Hall, Norfolk | Ditto. |
| Parsonage House, Great Snoring, Norfolk | During the reign of Henry VIII. |

Many of these buildings are illustrated in Pugin's "Examples of Gothic Architecture." The decorative details of the Manor House at East Barsham, and of the Parsonage House at Great Snoring, are particularly worthy of notice; the panelled friezes, cornices, and other ornamental work being constructed of terra-cotta moulded to the required form.

The use of *terra-cotta* for decorative panels and bas-reliefs appears to have been common during the reign of Henry VIII. The gateway of York Place, Whitehall, designed by Holbein, was decorated with four circular panels, which are still preserved at Hatfield Peveril, Hants.

The gateway of the Rectory in Hadleigh churchyard is very similar in character to that at Oxborough Hall, engraved in Pugin's work, above mentioned. It was restored very carefully in the middle of the 19th century; the terra-cotta then used being made at the Layham kilns, near Hadleigh.

In the time of Queen Elizabeth, bricks seem only to have been used in large mansions. For common buildings, timber framework, filled in with lath and plaster, was generally used, and this construction was much employed even when bricks were in common use, the brickwork, up to a late period, being merely introduced in panels between the wooden framing.

On the rebuilding of London after the Great Fire of 1666, brick was the material universally adopted for the new erections, a special Act (19th Car. II. c. 11) regulated the number of bricks in the thickness of the walls of the several classes of dwelling-houses. The following resolution of the Corporation of the City of London, passed about this time, is interesting:—"And that they (the surveyors) do encourage and give directions to all builders, for ornament sake, that the ornaments and projections of the front buildings be of rubbed bricks; and that all the naked parts of the walls may be done of rough bricks, neatly wrought, or all rubbed, at the direction of the builder, or that the builders may otherwise enrich their fronts as they please."

Much of the old brickwork still remaining in London, in buildings erected at the end of the 17th and beginning of the 18th century, is admirably executed. The most remarkable feature of the brickwork of this period is the introduction of ornaments carved with the chisel after the erection of the walls.

It was not till the close of the 18th century that bricks were subjected to taxation. An Act in 1784 (24th Geo. III. c. 24) imposed a duty of 2*s.* 6*d.* per thousand on bricks of all kinds. By another Act, ten years later (34th Geo. III. c. 15), the duty was raised to 4*s.* per thousand, and nine years later still (43rd Geo. III. c. 69), bricks were divided into "common" and "dressed" bricks, and separate rates of duty were imposed on each kind. These duties and those on tiles were as follows:—

## DUTIES ON BRICKS AND TILES.

[*Repealed* 1850.]

| | £ | *s* | *d.* |
|---|---|---|---|
| For every thousand bricks which shall be made in Great Britain, not exceeding any of the following dimensions, that is to say, ten inches long, three inches thick and five inches wide . . . . . . . . | 0 | 5 | 0 |
| For every thousand of bricks which shall be made in Great Britain exceeding any of the foregoing dimensions . | 0 | 10 | 0 |
| For every thousand of bricks which shall be made in Great Britain, and which shall be smoothed or polished on one or more side or sides, the same not exceeding the superficial dimensions of ten inches long by five inches wide . | 0 | 12 | 0 |
| For every hundred of such last-mentioned bricks, exceeding the aforesaid superficial dimensions . . | The duties on paving-tiles. | | |
| For every thousand of plain tiles which shall be made in Great Britain . . . . . . . . . | 0 | 4 | 10 |
| For every thousand of pan or ridge tiles which shall be made in Great Britain . . . . . . . . | 0 | 12 | 10 |
| For every hundred of paving tiles which shall be made in Great Britain not exceeding ten inches square . . | 0 | 2 | 5 |

| | £ | s. | d. |
|---|---|---|---|
| For every hundred of paving tiles which shall be made in Great Britain exceeding ten inches square . . . | 0 | 1 | 10 |
| For every thousand tiles which shall be made in Great Britain, other than such as are hereinbefore enumerated or described, by whatever name or names such tiles are or may be called or known . . . . . . . . | 0 | 1 | 10 |

N.B.—The said duties on bricks and tiles to be paid by the maker or makers thereof respectively.

In 1833 (3rd William IV. c. 11), the duties on tiles * were wholly repealed, and two years afterwards the duty on bricks was again raised, making the duty on common bricks 5*s.* 10*d.* per thousand.

The brick duties formed the subject of the 18th Report of the Commissioners of Excise Enquiry, 1836; and in 1839 these duties were repealed by the 2nd and 3rd Vict. c. 24, and a uniform duty of 5*s.* 10*d.* per thousand imposed on all bricks of which the cubic content did not exceed 150 cubic inches, without any distinction as to shape or quality. This Act was a great boon to the public as well as to the trade, as, in consequence of the removal of the restrictions on shape, bricks might be made to any required pattern; and moulded bricks for cornices, plinths, string-courses, etc., could be manufactured at a moderate price. Under the old regulations, also, the brick-maker was precluded from correcting any defect which might arise from warping or twisting in the process of drying, without making himself liable to pay the higher rate of duty. In 1850 the duty on bricks was entirely repealed.

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* By a curious oversight, this Act, which was intended to put *roofing tiles* on the same footing as slates, also repealed the duties on *paving* tiles, whilst *bricks* used for paving remained subject to duty as before. Thus a lump of clay put into a mould of 10 in. × 5 in. × 3 paid duty, but the same quantity of clay put into a mould 10 in. square was duty free, because it came under the denomination of a tile.

The number of bricks made annually in Great Britain is very great; just before the duty was repealed, a charge was made on about 1,800,000,000 bricks annually. In 1854 the number manufactured was estimated to be over 2,000,000,000, of which about 130,000,000 were made in the brickfields in and around Manchester, and about a similar number by the London brickmakers. Since that time the number had increased to an almost incredible extent.

Comparatively few bricks are made in Scotland, on account of the abundance of stone in that country. Those who are not practically connected with engineering works may find some difficulty in forming a clear conception of the immense number of bricks annually made for comparatively simple structures. Thus, a common turnpike road-bridge over a railway requires for its construction about 300,000 bricks; and the lining of a railway tunnel of ordinary dimensions consumes about 8000 for every yard in length, or about 14,000,000 bricks per mile.

The usual form of a brick is a parallelopipedon, about 9 in. long, $4\frac{3}{8}$ in. broad, and 3 in. thick, the exact size varying with the contraction of the clay. The thickness need not bear any definite proportion to the length and breadth, but these last dimensions require nice adjustment, as the length should exceed twice the breadth by the thickness of a mortar joint.

Bricks are also made of a variety of shapes for particular purposes. The largest common bricks now made measure, when burned, $9\frac{1}{2}$ in. long, $4\frac{5}{8}$ in. wide, and $3\frac{1}{16}$ in. thick, or thereabouts; these bricks weigh about 7 lbs. 15 oz. when burned. The smallest are

4½ in. by 2 in. by 2 in., but these are only used for fireplaces and other decorative work.

*Yellow* clamp-burned bricks are made in the vicinity of the metropolis, and in other situations where similiar material and fuel are readily obtained.

*White* bricks are made from the plastic clays of Devonshire and Dorsetshire, and also Cambridgeshire, Norfolk, Suffolk, and Essex, as well as in other counties.

*Red* bricks are made in almost every part of England, notably in Leicestershire, Accrington, Ruabon, and near Peterborough, where immense quantities of machine-made bricks are annually turned out; the *fine red* or cutting brick is very largely made in Hampshire and Berkshire.

*Blue* bricks are made in Staffordshire, and are much used in various parts of England for engineering purposes. Other varieties of bricks are made for special purposes and in localities where special clays exist. The chief varieties of bricks supplied to the London market are mentioned near the end of Chapter III.

Sound and well-burned bricks are generally of a clear and uniform colour, and when struck together will ring with a metallic sound. Deficiency in either of these points indicates inferiority.

Bricks sufficiently light to float in water were known to the ancients. Their manufacture, however, was completely lost until rediscovered at the close of the 18th century by M. Fabbroni, who succeeded in making floating bricks of an infusible earth called fossil meal, which is abundant in some parts of Italy. Bricks made of this earth are only one-sixth of the weight of common clay bricks, on which account they would be of great service in vaulting church roofs, and for similar purposes. Ehrenberg, the eminent German microscopist, showed that this earth consists almost entirely of the frustules or siliceous skeletons of various kinds of minute water-plants.

The ordinary light bricks now used are made by mixing sawdust with the clay. This burns out in the kiln and leaves very porous bricks of low weight, though still relatively heavier than water.

Bricks vary greatly in their strength, a point to which, although of considerable importance, very little attention is paid. There is a striking difference in this respect between modern and ancient hand-made bricks, a difference very much in favour of those made centuries ago; and perhaps the weakest bricks made are the grey stocks supplied by London makers. Reliable comparative results are difficult to obtain, but the following figures are the averages of a considerable number of tests of each variety of bricks named. These tests were made by the reviser of the present volume in his capacity as technical adviser to various authorities during a period of about eight years.

CRUSHING STRENGTH.

| | Tons per square foot. |
|---|---|
| London Grey Stock Bricks | 89 |
| Suffolk White Bricks (Gault) | 135 |
| Essex Red Sand Stocks | 96 |
| Leicestershire Red Bricks (wire cut) | 269 |
| Fletton Bricks (semi-dry process) | 250 |
| Staffordshire Blue Bricks | 785 |
| South Yorkshire Bricks (Stiff plastic process) | 540 |
| Dutch Clinkers (Blue bricks) | 587 |
| Rubber Bricks and Cutters (very variable) | 70 |

In Germany, the minimum crushing strength of bricks permitted to be used is:

| | Tons per square foot. |
|---|---|
| Blue bricks, clinkers and pavers | 318 |
| First class building bricks | 136 |
| Common bricks | 90 |
| Sand-lime bricks | 128 |

## CHAPTER II.

### GENERAL PRINCIPLES OF THE MANUFACTURE OF BRICKS.

THE processes employed in the manufacture of bricks differ very greatly in various parts of the country. In some districts the clay is ground between rollers, and no pug-mill is ever used. In others, both rollers and pug-mills are employed. In the neighbourhood of London the clay is commonly passed through a wash-mill. Equal differences exist in the processes of moulding and drying. The form of the kiln also varies greatly. In some places a common "open" kiln is employed. In Essex and Suffolk some kilns have arched furnaces beneath their floors; in Staffordshire bricks are fired in circular domed ovens called cupolas; whilst near London kilns are not used, and bricks are burned in "clamps," the fuel required for their vitrification being mixed with the clay in the process of tempering.

In the following pages the practice of brickmaking as carried on in Nottinghamshire, Staffordshire, Suffolk, Yorkshire, etc., and in the neighbourhood of London, is described at considerable length, and although the practice of almost every county presents some local peculiarity, the reader who has carefully read these descriptions should be able to form a tolerably correct judgment as to whether the process of manufacture in any district is conducted in a judicious manner; or whether the brickmaker has merely followed the practices handed down by his predecessors without any consideration as to the possibility of improving upon them.

At the same time, study of this kind can never give more than a limited competency to express a valuable opinion, and unless unnecessary risks are to be run in the opening of a new brick works or in the alteration of an existing one, an expert on the subject should always be consulted. The advice of kiln builders, manufacturers of machinery, and even that of other brickmakers is usually biassed in favour of one type of kiln, machine or process, so that, when seeking assistance, it is essential that an entirely independent specialist should be consulted.

Brickmaking may, in fact, be viewed in two ways —as a science, and as an art. The former has been little studied, and is imperfectly understood; whilst the latter has been brought to great perfection.

It is only within the last thirty years or so that the value of scientific investigation, when applied to brickmaking, has been appreciated, and even at the present day the majority of clayworkers still rely chiefly on "rule of thumb" and "tradition."

The manufacture of porcelain and pottery may be said to have possessed a "science" (of Ceramics) for many years, but in the branch of manufacture which concerns itself with brickmaking the numerous investigations which have been made have not, as yet, been systematically arranged, except to a very small extent.

To attempt to supply this in the present volume is impossible—the author's intention being primarily concerned with the *art* of brickmaking—but scientific reasons for various processes will be found where the opportunity arises for them to be expressed. The reader who is interested in the scientific aspect of brickmaking should consult the "Clayworker's Handbook," "British Clays and Shales," and similar volumes. A handy little volume, by the late G. F. Harris, entitled "The Science of Brickmaking," is also valuable in this connection, though very limited in its scope.

Before entering upon the practical details of the subject, however, it is necessary that the reader should have some knowledge of the general principles of brickmaking, and of the nature of the processes employed; these are considered in the present chapter.

The whole of the operations of the brickmaker may be classed under five heads, viz. (*a*) Selection and preparation of brick-earth; (*b*) Tempering; (*c*) Moulding; (*d*) Drying; and (*e*) Burning.

### THE SELECTION OF BRICK-EARTH.

The qualities to be sought in bricks for building purposes may be thus enumerated: *Soundness*, that is, freedom from cracks and flaws; *hardness*, to enable them to withstand pressure and cross strain;

*regularity of shape*, that the mortar by which they are united may be of uniform thickness to ensure uniformity of settlement; *uniformity of size*, that all the bricks in a course may be of the same height; *uniformity of colour*, which is of importance only in facing and ornamental work; *facility of cutting*, to enable the bricklayer to cut them to any given shape in executing all kinds of gauged work; lastly, for furnace-work, and all situations exposed to intense heat, *infusibility*, or *refractoriness*.

Success in attaining the desired end depends chiefly on a proper selection of brick-earths and on their judicious preparation before commencing the actual process of brickmaking, as well as on the drying and burning of the bricks.

The brickmaker deals with *natural clays* only, the constitution of which, when more or less ascertained in respect to his object, he may modify by the addition of other mineral bodies, such as sand, ashes, etc., or by the mechanical extraction of naturally-mixed matter, as sand, pebbles, pyrites, etc., and whose physical qualities he may alter by mechanical means —grinding, washing, etc.

The choice of a clay that shall answer well for the brickmaker's use cannot be completely and satisfactorily made without extensive trials on a sufficiently large scale. As such trials are costly and not always conclusive, it is well to precede them by a series of tests—carried out by a competent man *—in order to ascertain the general characteristics of the material both in its raw state and when burned.

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* Special training and appliances being necessary in carrying out these tests, it is useless to expect reliable results to be obtained without the use of a specially fitted laboratory. Very few (if any) public analysts have the special appliances or expert knowledge required.

The precise nature of the tests to be made will depend on the purposes for which it is proposed to employ the material, but they will usually consist of (*a*) the production of a few specimen bricks, (*b*) determination of the shrinkage on drying and burning, (*c*) the porosity of the burned brick, (*d*) its crushing strength, (*e*) its permeability to water, (*f*) the fusibility of the material, and (*g*) its plasticity and binding power. A chemical analysis of the clay is desirable if firebricks are to be manufactured, but for building bricks a mechanical analysis—separating the material into stones, gravel, coarse sand, fine sand, silt, and "true clay"—will determine its composition with sufficient accuracy. This "mechanical analysis" is sometimes termed "a washing test."

In making a chemical analysis it is important that the correct constituents are determined. Many chemists are satisfied to report on constituents which are relatively unimportant, and, under the term "alkalies," (p. 28), etc., to include all the others without making any determination of them. Such analyses are *utterly useless* for the purposes of the brickmaker, as it is these undetermined constituents which exercise the most deleterious effect upon the material. The case is precisely analogous to the "arsenic in beer" scare of a few years ago. Hundreds of beers were analyzed, but because no arsenic was sought for, no mention of this poison occurred in the reports. Nevertheless, it was there all the time, and was found when special attention was drawn to it.

This is an additional argument for employing a specially trained chemist—a specialist in clay working—for making such tests. The names of such specialists can be obtained from the trade papers.

There is probably no substance so indeterminate in its composition as clay. Regarding it, as Lyell does,* as "nothing more than mud derived from the decomposition of wearing down of rocks," it must necessarily contain a variety of substances, such as oxide of iron, lime, magnesia, potash, silica, bitumen, fragments of undecomposed rock, etc. These substances impair the plasticity of the clay, and impress upon it certain characters which are of more importance to the manufacturer than to the chemist, or the geologist, though it is the two latter who are chiefly responsible for definitions of the term "clay."

The following analyses—from various sources—indicate the enormous differences between the compositions of various clays. The figures given are typical, though clays bearing the same titles frequently show considerable variations among themselves.

| Constituents. | Washed china clay | Stourbridge fireclay | Pipeclay. | Loam. | Ball clay. | Red brick clay. A. | Red brick clay. B. | Marl. | Gault. | Fuller's earth. |
|---|---|---|---|---|---|---|---|---|---|---|
| Silica . . . | 46 | 65 | 54 | 67 | 46 | 49 | 63 | 32 | 44 | 44 |
| Alumina . . | 40 | 22 | 32 | 26 | 38 | 24 | 20 | 10 | 15 | 36 |
| Iron oxides . . | — | 2 | — | 3 | — | 8 | 5 | 3 | 6 | 2 |
| Lime . . .<br>Magnesia . . | 1 | 1 | 1 | 1 | 2 | 7 | 2 | 22 | 17 | 6 |
| Potash and soda . | — | — | 1 | 1 | 0 | 1 | 2 | 2 | — | 1 |
| Water, etc. . . | 13 | 10 | 12 | 2 | 14 | 11 | 8 | 31 | 18 | 11 |

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* "Manual of Elementary Geology" (1855), p. 1

The essential constituent of all clays—sometimes termed "true clay" or "clay substance"—appears to be a definite chemical compound, which is a hydrated aluminium silicate ($Al_2O_32SiO_2+2H_2O$), but it is not possible, at present, to make any definite statement upon this matter, owing to the lack of sufficiently accurate data. The very positive statements made by some engineers and other writers, not fully acquainted with the facts, are either erroneous in that they do not cover certain characteristics of clay, or they are so wide that they include many substances entirely unsuitable for the purposes for which clay is used.

The chief characteristic of all clays is their *plasticity* when moist, though they possess this property to very varying degrees, some typical clays being almost devoid of plasticity. Others contain so much non-plastic material (sand, etc.) that until this is removed their plasticity is inappreciable. Thus, in loam, if the sand be in large proportion, and in marl, if calcareous matters abound, so as to deprive either material of plasticity, it ceases to be "clay." There are also certain silicates of alumina which are not plastic; such as bole, lithomarge, and fullers'-earth. Bole consists chiefly of a hydrated bisilicate of alumina, in which a portion of the alumina is replaced by sesquioxide of iron. Lithomarge also contains iron, and is sometimes so compact as to be used for slate-pencils. Fullers'-earth contains lime, magnesia, and iron, in addition to its principal ingredients.

A rough method of measuring the plasticity of different clays is to note the length to which a cylinder of each can be drawn out in a vertical direction without breaking. In such a comparison, the clays must, of course, be ground equally fine, be subjected to the same mixing treatment, and must have a suitable proportion of water. The latter is such that when a ball of clay paste is squeezed in the hand it does not adhere to the skin because of excessive moistness, nor does it crack at the edges because it is too dry. Different clays require different proportions of water to develop their plasticity fully.

It is commonly stated that the ingredient that confers plasticity on clay is its alumina; and yet, strange to say, pure alumina alone, whether gelatinous or after having been dried and ground up with water for a long time, never gives a plastic paste. A material of the same chemical composition as clay may be formed, but it never possesses plasticity, and is quite different from clay in appearance and behaviour. The gelatinous state of alumina is not the cause of plasticity in clay; for silica may be made as gelatinous as alumina, and silica is certainly not the cause of plasticity. It may be that the strong affinity of alumina for water (retaining a portion of it even when near a red heat) may be the cause of this property—just as turpentine renders wax plastic; and water and gluten confer the same property on starch.

Clay ceases to be plastic when its chemically combined water has been driven off. Nevertheless, water cannot be said to be the cause of plasticity as a general property, since melted glass is a more perfect example of plasticity even than clay; and few substances are more plastic than sealing-wax at a certain temperature.

At the same time, the presence of water appears, in some way, to be essential to the plasticity of clay, as on removing it clays cease to be plastic. It is not improbable that the water-particles diffused through the material act—in some manner as yet imperfectly understood—as a lubricant; the minute, solid, and rigid particles slip over each other, as it were, upon liquid rollers, just as two plates of glass or metal slip over each other when a film of water is interposed.

As clay particles are amongst the very smallest known, it is not impossible that their plasticity may, in part, be due to the very small distances between them, though the method of arranging the particles of clay at that precise distance that shall impart plasticity, is one of Nature's secrets that no one has yet succeeded in penetrating. It may be that the circumstances under which clay is formed and deposited, or the time that has elapsed since its formation, or the pressure of the superposed layers, may have so arranged the particles as to enable them to become plastic when the proper proportion of water is added. It may be that a certain state of disintegration is required on the part of the alumina and the silica, so that their proximate elements shall be neither too fine nor too coarse; or it may be that the silica, in combining with the alumina, separates the atoms of the latter to precisely those distances required for the development of the property; or, lastly, the presence of a small portion of animal or other organic matter in clay may have something to do with this remarkable property.

An extensive series of experiments, by Delesse, show the presence of animal matter in quartz and various rocks, where its presence had not previously been suspected; and this may have as important an effect in modifying the properties of a mineral as the presence of minute portions of bodies, formerly entered as impurities, has in producing pseudomorphous crystals. This observation is interesting because many clays emit a peculiar odour when breathed upon or moistened. It has not been conclusively proved that this odour is solely due to organic matter, though this is extremely probable.

Numerous other theories as to the cause of plasticity have been propounded, including one suggesting that it is due to the colloidal nature of the clay particles, but none are entirely satisfactory.

So far it has not been found possible to produce a plastic clay from artificially formed materials, as the conditions under which plasticity is produced are not known. The action of water at high temperatures and under great pressure has been thought to produce a plastic material from felspar, but the experiments were on too small a scale to make this absolutely certain. At present, it is only possible to confer a fictitious property of this kind on mineral substances by taking advantage of another property which it somewhat resembles, namely, *viscosity* or *viscidity*. Viscosity differs from plasticity in that the viscous body does not retain the form impressed upon it when the force is removed, as a plastic body does. The materials of the old soft porcelain of Sèvres had no plasticity; but this property was conferred by means of soft soap, parchment size, or gum tragacanth.

On heating sufficiently, all clays lose their plasticity and cannot regain it, so that, on burning, they are converted into rigid bodies. Little is known as to the minimum temperature at which clay loses its plasticity when heated. Dorset ball clays can be heated to the boiling-point of mercury (365° C.) with impunity, but some other clays lose their potential plasticity at or near this temperature. At a red heat all clays become rigid, and if the combined water present can be driven off at a lower temperature, the potential plasticity will, apparently, be lost at that temperature.

When a clay is heated, the first effect is to drive off the hygrometric water, or "water of formation." The clay then becomes dry, but is not chemically changed; it does not cease to be plastic when cooled and moistened. On continuing to raise the temperature the chemically combined water is separated, and the clay undergoes a molecular change, which prevents it from taking up water again, except mechanically. With the loss of this chemically combined water, clay ceases to be plastic. On further heating, clays tend to undergo partial fusion. When this has occurred to a sufficient extent for the fused material to fill the pores completely, the brick or other article becomes impervious to water, and is said to be "vitrified." Refractory clays—which are usually composed of "true clay" with silica and but little other impurities—are difficult to vitrify, and require the highest temperatures obtainable for this purpose. Most calcareous clays, on the contrary, vitrify sufficiently to lose their shape at temperatures below the melting-point of cast iron.

The varieties of clays used for brickmaking are so numerous that they cannot be all described in a volume devoted to the rudiments of the art. Readers desiring more detailed information should consult "British Clays and Shales," by the reviser of the present work. The following varieties of clay are, however, of sufficient importance to be mentioned here:—

*White-burning clays*, composed chiefly of alumina, silica and water, and typically represented by the china clays of Cornwall and the ball clays of Dorset and Devon. These clays are regarded as relatively "pure," and are only used to a very limited extent in brickmaking, as other materials of lesser value are more readily obtainable.

*Marls*, which may be defined as clay earths containing a considerable proportion of lime in the form of chalk or limestone. The bricks made from these are often almost white, but this is not due to the purity of the material, but to the combination of the iron oxide with the lime in the clay. Marls are easily fusible, and give a characteristic effervescence when a little hydrochloric acid is poured upon them.

The term "marl" is also used for certain friable rock clays in some parts of the country, but this is an undesirable use of the word.

In working the marls of the Midland districts, much trouble is experienced from the veins of skerry or impure limestone with which these earths abound. If a small piece of limestone, no bigger than a pea, is allowed to remain in the clay, it may destroy any brick into which it finds its way. The carbonic acid is driven off by the heat of the kiln, and forces a vent through the side of the brick, leaving a cavity through which water finds its way, and the first sharp frost to which such a brick may be exposed may suffice to destroy the face. Smaller pieces are less harmful.

*Loams* are clays containing a large proportion of sand, so that they are much easier to work than are tougher clays.

*Shales* are indurated clays which have been subjected to such compression as to make them partake of the nature of rocks. Shales show but little plasticity unless they are ground to powder before being moistened. Under the term "shale" are included most of the refractory fireclays, but red-burning materials which are by no means so refractory are obtained from the more impure shales, and are largely employed for brickmaking.

*Fireclays* are those which are refractory, or capable of resisting very high temperatures in furnaces. They contain but small proportions of lime, iron, or other metallic oxides and similar substances which act as fluxes. Usually they contain a considerable proportion of silica in excess of that occurring in china and ball-clays.

They are generally obtained from pits of considerable depth—such as coal pits—chiefly in the districts covered by the Coal Measures.

Formerly, of all British fireclays, that of the old mines at Stourbridge was considered to be the best. Next in esteem are the Welsh fire-bricks, but they will not bear such intense heat. Excellent fire bricks are made near Newcastle, Glasgow, Lancashire and Cheshire, and are considered, by the manufacturers, to be quite equal in value to the bricks made from what is termed "new mine clay" at Stourbridge.

The composition and quality of clays in contiguous beds in the same pit, and even of clay from the same horizontal bed, may vary. The relations between the silica and alumina are extremely variable, and, accordingly, the formulæ which have been proposed to express their rational constitution are very discordant. This is in great measure to be explained by the fact that in many clays a large proportion of silica exists uncombined, either as sand or in an extremely fine state of division.

Bricks made of refractory clay, containing no lime or alkaline matter, are *baked* rather than burned; and their soundness and hardness depend upon the fineness to which the clay has been ground, and the degree of firing to which it has been exposed.

In order to give articles made of fireclay the power of resisting changes in temperature and the prolonged action of heat, the raw clay is frequently mixed with burned clay (grog) ground to a coarse powder. Broken crucibles, old fire-bricks, and old glass pots ground to powder are also mixed with fire-clay, though these are not so satisfactory as grog which has been specially prepared.

*Boulder clays* have been produced by glacial action, and may usually be distinguished from other clays by the number of rounded stones they contain. Boulder clays are extremely irregular in composition, but when carefully selected and prepared, they make satisfactory common bricks, with a considerable proportion of bricks suitable for facing purposes.

The term *brick-earth* is used to distinguish clays which can be made into bricks without much mechanical treatment, from the harder rock clays and shales which must be ground before they can be used.

Hence in the smaller yards brick-earths are employed whenever possible, and the amount of machinery required is thereby reduced to a minimum.

The *Impurities* in clays vary greatly in their importance. It is very seldom that the common clays are found to be free from lime and other fluxes; and when these are present in certain proportions, the silica of the clay becomes fused at a moderate heat, and cements the mass together. Some earths are very fusible, and, when used for brickmaking, great care is requisite in firing the bricks to prevent them from running together in the kiln. Sometimes these "impurities" are essential to the commercial utility of the clay, for a material which, if pure, would shrink and crack excessively, may prove excellent because it contains sufficient sand or other suitable non-plastic material to reduce its shrinkage to within convenient limits.

Thus, if a clay is so plastic that it shrinks and cracks in drying, however carefully the operation is conducted, and will not stand firing without rending and warping, the addition of any substance which will neither combine with water nor is subject to contraction, greatly remedies these defects, whilst the plastic quality of the clay is not materially affected. For this reason the strong clays are mixed with milder earth or with sand. The loams and marls used for brickmaking in the neighbourhood of London are mixed with chalk and sifted breeze for the same purpose, and also to improve the colour and effect the fluxing of the earth, as is described later.

Hence, for ordinary bricks it is not important whether a clay contains a little sand, providing the mixture is sufficiently plastic and the proportion of sand not excessive. As already mentioned the addition of sand is essential in some cases.

*Lime* is frequently a serious impurity in brick-clays. If in the form of exceedingly fine grains (as chalk) its effect is chiefly to reduce the colour of the clay, but if the grains are coarser (as ground limestone) it may seriously weaken the bricks and even cause them to break in pieces.

Larger grains of chalk or limestone burn into caustic lime in the brick-kiln, and if afterwards the brick absorbs moisture and carbonic acid, the contained nodules of lime "slack," and swell in their places, and so burst the brick to pieces. This is one of the most prevalent evils of the ill-made bricks which are almost universal in central Ireland, arising from the wide diffusion of limestone gravel in that country, and the total neglect of grinding or efficient sifting of the clay.

*Pebbles*, whether of flint or limestone, should be picked or screened out. The former are seldom properly crushed on account of their hardness, and the latter are disastrous as described above.

*Iron pyrites* is a frequent impurity in clays, and a cause of black slag-like discoloration. In the brick-kiln the pyrites is partially decomposed: oxide of iron and basic sulphides of iron remain. When at an after-period these are exposed to air and moisture, which are absorbed to all depths in brick, oxidation takes place, sulphate of iron, and frequently also sulphates of lime or alums (sulphates with double bases), are formed, and, crystallizing within the mass of the brick, may split it to pieces.

In buff-burning bricks, iron pyrites forms black spots or slag-like masses according to its fineness.

*Iron compounds*—apart from pyrites just mentioned—confer a red or black colour on clays containing them in sufficient quantity. Their action is described more fully under "Colour" (p. 30).

*Common salt* is nearly always present in minute quantity in clays and is generally unimportant; but when these are taken from the seashore or beneath the sea-washes, or from localities in and about the salt formations (trias), they frequently, though in all other respects excellent clays, are unfit for burning into good bricks. Common salt is not only a powerful flux when mixed even in small proportion in clays, but possesses the property of being volatilized by the heat of the brick-kiln, and in that condition it carries with it, in a volatile state, various metallic compounds, as those of iron, which exist in nearly all clays, and also act as fluxes. The result is that bricks made of such clays tend to fuse, to warp, twist, and agglutinate together upon the surfaces long before they have been exposed to a sufficient or sufficiently prolonged heat to burn them to the core into good hard brick. "Place bricks" can be made of such clay, but nothing more; and these are always bad, because never afterwards free from hygrometric moisture.

Much *carbonaceous matter* naturally mixed in clays is also objectionable, for when not burnt completely and in the kiln, which is sometimes difficult with the denser clays, the bricks are of a different colour in the interior and exterior, and will not bear cutting for face-work, without spoiling the appearance of the brickwork. But, worse than this, such bricks when wetted in the wall occasionally pass out soluble compounds and cause discoloration or "scum."

*Alkalies* is a term used to comprise various compounds of potash and soda occurring in varying, but usually small, quantities in clays. They are powerful fluxes, causing, in combination with the silica, alumina and lime in the clay, the formation of a more easily fusible compound which, if formed in sufficient quantity, may cause the collapse of the bricks. These combinations usually take the form of glass, the chief characteristic of which is the *vitreous* fracture. When such glasses are formed with any oxides of earthy bases also present, they may assume crystalline or porcellaneous textures when cooled.

It is for this reason that clays which are required to resist high temperatures must not contain more than a very small proportion of alkalies or lime compounds.

Some of this glassy material is essential for the production of the strongest bricks.

Porcelain, earthenware, and hard brick (such as the Staffordshire or Flintshire blue bricks) consist in substance of such compound glasses, diffused throughout their substance uniformly, and binding together the finely-diffused particles of the excess of fluxes which are present, or binding together the fragments of uniformly-diffused clay, silica (sand, ground flint), etc. The degree of fusibility, or of partial fusibility (agglutination), of any hard-baked brick thus depends not only upon the chemical nature of the constituents of the clay, but upon the proportions in which these are present.

It is a curious fact that although mixtures of the various constituents of clay are extremely fusible, yet any one of them heated alone is practically infusible. Thus, lime and silica heated separately cannot be fused in an ordinary kiln, but if mixed in suitable proportions a glass can be formed at a moderate temperature.

The laws, so far as they have been ascertained, upon which the induration or agglutination of clays by heat depend, have not been sufficiently studied to admit of definite statement in a rudimentary treatise. The phenomena are so highly complex that any study of them is extremely difficult, if not impossible, to those who have not had a thorough University training in physical chemistry.

*Burning*, or heating bricks in a kiln, is for the purpose of making them durable. The effect of this heating depends largely on the composition of the material of which they are made. Thus, simple heating which makes the material rigid, but no more, is known as *baking*. When the heating produces a partial fusion of the material so that, on cooling, the unfused particles are firmly cemented together, the bricks are said to be *burned*. Hence, bricks may be divided into two classes—*baked* bricks made from the refractory clays, and *burned* or vitrified bricks made from the more fusible earths. When making this classification it should, however, be remembered that an underfired brick—which has not been sufficiently heated—will be classed with the baked bricks, whilst a brick which has been spoiled by overheating will be classed with the burned ones.

For some purposes bricks must be porous, and baking is then necessary; for others imperviousness is desirable, and burned bricks are then required.

The fusible earths are the most difficult of treatment, as there is considerable practical difficulty in obtaining a sufficient degree of hardness without risking the complete fusion of the bricks. When bricks made from some fusible clays are burned without great care and skill, they are usually hard on the outside only and are soft internally.

The *colour* of bricks depends on the composition of the material and the manner in which it is treated in the kiln. The chief colorant is the iron oxide in the clay, which does not show until the material has been heated, and cannot be determined from an inspection of the raw material.

This should be borne in mind, because brickmakers often speak of clays as red clay, white clay, etc., according to the colour of the bricks made from them, without any reference to their colour in the unburned state. This latter is of little or no importance to the brickmaker.

Bricks made from clays which are almost free from iron oxide burn white; if what little iron is present is largely in the form of pyrites, the burned bricks will be buff-coloured with black spots, and generally, for light-coloured bricks the clays must be almost free from iron compounds, and the latter must be peroxidized as little as possible in the burning.

If iron be present in clay without lime or similar substances, the colour produced at a moderate red heat will be red, the intensity of colour depending on the proportion of iron. If the clay contains sufficient iron oxide and is slightly fusible, an intense heat vitrifies the outside of the mass and changes its colour, as in the case of the "blue" Staffordshire bricks, which, when burned in the ordinary way, are of a red colour, which, however, is changed to a greenish-blue by longer firing at a greater heat. This is due to the reducing action of the kiln-gases at the higher temperature, and the formation of dark-coloured iron silicates. In some cases a little manganese oxide is added to the clay to produce a dark colour.

In a fully oxidizing atmosphere, with plenty of air in the kiln, clays containing only a small amount of fluxes and a considerable quantity of iron oxide give a large range of colour, from the lightest tawny yellow, through full yellow, orange, and to the rich scarlet of red facing-bricks, almost as bright as red lead.

To obtain the last-named colour the clay must be comparatively pure, except for the ferric oxide present, and must be very carefully heated. If the heat is raised sufficiently to cause partial fusion, the colour will be darkened and, to some extent, spoiled. The addition of lime changes the red produced by the oxide of iron to a cream or white, according to the proportion of lime present, whilst magnesia brings it to a yellow. Few clays produce a clear red, the majority burning to different shades of colour, varying from reddish-brown to a dirty red, according to the proportion of lime and similar substances which they contain.

Some clays, as the plastic clays of Suffolk, Devonshire, and Dorsetshire, burn of a clear white, as may be seen in the Suffolk white bricks, which are much esteemed for their soundness and colour. The London malms have a rich brimstone tint, which is greatly assisted by the nature of the sand used in the process of moulding.

By employing metallic oxides and the ochreous metallic earths, ornamental bricks may be made of a variety of colours. This is, however, a branch of brickmaking which has received little attention in this country, although, with an increasing taste for polychromatic decoration, it is well worthy of consideration. In this connection it is remarkable how much beauty the German architects contrive to extract out of the judiciously-arranged patterns producible from mere common brick, combined with delicate and beautiful harmonies of tint and colour.

With a given constitution of brick-clay, the final colour of the burned brick depends upon a large number of conditions in the process of firing, but mainly upon two, viz. what proportion of *air* be admitted to the combustion of the fuel in the kiln, *i.e.* whether the brick be finally burned with an oxidizing or a deoxidizing flame; and whether or not, or in what proportion, steam or water be present in the brick, or be brought in the state of vapour in contact with it, when at elevated temperatures.

Upon an exact knowledge of the effects producible by the play of these conditions upon the brick in burning rests the power of the brickmaker to vary or maintain with certainty the good colour of his ware, or to effect any desirable changes of colour of which his material may be susceptible.

## PREPARATION OF MATERIAL.

*Unsoiling.*—The first operation is to remove the mould and top soil, which is wheeled away, and should be reserved for resoiling the exhausted workings when they are again brought into cultivation. In London the vegetable mould is called the *callow*, and the operation of removing it, *encallowing*.

*Clay-digging and Weathering.*—The material is dug in the autumn, and wheeled to a level place prepared to receive it, when it is heaped up to the depth of several feet, and left through the winter months to be mellowed by the frosts, which break up and crumble the lumps. At the commencement of the brickmaking season, which generally begins in April, the clay is turned over with shovels, and tempered either by spade labour or in the pug-mill; sufficient water being added to give plasticity to the mass.

During these operations any stones which may be found must be carefully picked out by hand, which is a tedious and expensive operation, but one which cannot be neglected with impunity, as the presence of a pebble in a brick generally causes it to crack in drying, and makes it shaky and unsound when burned. If the materials to be used are much mixed with gravel, the only remedy is to wash them in a trough filled with water, and provided with a grating sufficiently close to prevent even small stones from passing through, and by means of which the liquid slip runs off into pits prepared to receive it, where it remains until, by evaporation, it becomes sufficiently firm to be used. This process is used in making bricks which require to be of perfectly uniform texture throughout their whole substance; but it is tedious and expensive.

It may be here observed that sufficient attention is not generally paid to the preparation of brick-earth, as it too frequently happens that the clay is dug in the spring instead of the autumn, in which case the benefit to be derived from the winter frosts is quite lost. The use of rollers to a certain extent counterbalances this; but bricks made of clay that has been thoroughly weathered are sounder and less liable to warp in the kiln.

*Washing.*—In the neighbourhood of London, for marl or *malm* bricks, the earth is ground to a slip in a wash-mill, and mixed with chalk previously ground to the consistence of cream; this slip, or, as it is technically called, malm, is run off through a fine grating into pits prepared to receive it, and there left until, by evaporation and settlement, it becomes of sufficient consistency to allow a man to walk upon it. It is then *soiled, i.e.* covered with siftings from domestic ashes, and left through the winter to mellow. At the commencement of the brickmaking season the whole is turned over, and the ashes thoroughly incorporated with the earth in the pug-mill. In making common bricks, the whole of the earth is not washed, but the unwashed clay is heaped up on a prepared floor, and a proportion of liquid malm poured over it, after which it is soiled in the same way as for making malms.

These processes are well calculated to produce sound, hard, and well-shaped bricks. The washing of the clay effectually frees it from stones and hard lumps, whilst the mixing of the chalk and clay in a fluid state is to ensure the perfect homogeneity of the mass, and enables the lime to combine with the silica of the clay, which would not be the case unless it were in a state of minute division.

There are very few earths suitable in their natural state for making cutter-bricks. These are therefore usually made of washed earth mixed up with a proportion of sand. Without the addition of sand the brick would not bear rubbing, and it would be very difficult to bring it to a smooth face.

*Grinding.*—Where the material is of a rocky nature, it must be ground before it can be made into a paste. If any small stones occur, and are not removed by washing, they must be crushed in a grinding plant, or they may cause disintegration of the bricks, especially if they are largely composed of limestone like the "skerry" in the Midland marls. To remedy this serious evil, cast-iron rollers are now generally used throughout the Midland districts for grinding the clay and crushing the pieces of limestone found in it, and their introduction has been attended with very beneficial results. The clays of the Coal Measures often contain ironstone, which requires to be crushed in the same manner.

In many yards the grinding of the clay is made to form part of the process of preparation, the routine being as follows:—clay-getting, weathering, turning over and wheeling to mill, grinding, tempering, and moulding. In Staffordshire the clay is not only ground, but is also pugged in the process of tempering, as described in Chap. VI.; the routine is then as follows: clay-getting, weathering, turning over, grinding, pugging, moulding.

*Tempering.*—The object of tempering is to bring the prepared brick-earth into a homogeneous paste, for the use of the moulder.

The old-fashioned way of tempering was to turn the clay over repeatedly with shovels, and to tread it under the feet of horses or men, until it acquired the requisite plasticity. Thus, on the railway line between Nottingham and Grantham, several millions of bricks have been made as follows:—The clay is first turned over with the spade, and watered and trodden by men or boys, who, at the same time, pick out the stones. It is then wheeled to the mill and ground; after which it is turned over a second time, and then passed at once to the moulding table.

This method is still practised in many country yards; but where the demand for bricks is extensive, machinery is usually employed, the clay being either *ground* by rollers or *pugged* in a pug-mill. This latter process is also called grinding in some districts, so that, in making inquiries respecting the practice of particular localities, the reader should be careful that he is not misled by the same name being applied to processes which are essentially different.

When rollers are used in the preliminary processes, the labour of tempering is much reduced. Their use is, however, occasionally confined to the process of tempering, which is then effected as follows:—The clay, which has been left in heaps through the winter to mellow, is turned over with wooden shovels (water being added as required), and wheeled to the mill, where it is crushed between the rollers, and falls on a floor below them, where it is again turned over, and is then ready for use.

When the clay is sufficiently mild and free from lime and ironstone as not to require *crushing*, tempering is done by spade labour and treading or pugging; but in the districts where rollers are used, brick-earths are generally so indurated that a great proportion could not be rendered fit for use by the ordinary processes. The advantages and disadvantages of the use of rollers are considered at some length in Chap. V.

Although in some country places, where the demand for bricks is very small, tempering is still performed by treading and spade labour, the pug-mill is very extensively used near London, and in most places where the brick-earth is of mild quality, so as not to require crushing, and the demand for bricks sufficiently constant to make it worth while to erect machinery.

The pug-mill used near London is a wooden tub, in shape an inverted frustrum of a cone, with an upright revolving shaft passing through its centre, to which are keyed a number of knives, which, by their motion, cut and knead the clay, and force it gradually through the mill, whence it issues in a thoroughly tempered state, fit for the use of the moulder. Some contend that the pug-mill is no improvement on the old system of tempering by manual labour; but, without entering into this question, there can be no doubt that it does its work very thoroughly, and its use prevents the chance of the tempering being imperfectly performed through the negligence of the workmen.

In Staffordshire and in other places with large brickyards, steam power is used for driving both rollers and pug-mill, and the case of the latter is usually a hollow cast-iron cylinder instead of being made of wood. Horizontal pug-mills are also substituted for vertical ones.

*Moulding.*—A brick-mould is a kind of box without top or bottom, and the process of moulding consists in dashing the tempered clay into the mould with sufficient force to make the clot completely fill it, after which the superfluous clay is stricken with a slip of wood termed a *strike*, and the newly-made brick is either turned out on a drying floor to harden, or on a board or pallet, on which it is wheeled to the hack-ground. The first mode of working is known as *slop moulding*, because the mould is dipped in water, from time to time, to prevent the clay from adhering to it. The second method may be distinguished as *pallet moulding* or *sand moulding*; as in this process the mould is not wetted, but sanded. These distinctions, however, do not universally hold good, because in some places slop-moulded bricks are turned out on pallets.

These differences may, at first sight, appear trivial, but they affect the whole economy of a brickworks. In slop moulding, the raw bricks are shifted by hand from the moulding table to the drying floor, from the drying floor to the hovel or drying shed, and from thence to the kiln. It is, therefore, requisite that the works should be laid out so as to make the distance to which the bricks have to be carried the shortest possible. Accordingly, the kiln is placed in a central situation in a rectangular space, bounded on two or more sides by the hovel, and the drying and working floors are formed round the outside of the latter. There are, of course, some exceptions; but, where practicable, the drying floor and hovel are placed close to the kilns.

In the process of *slop moulding* the newly-made brick is carried, mould and all, by a boy to the flat, or drying floor, on which it is carefully deposited; and whilst this is being done, the moulder makes a second brick in a second mould, the boy returning with the first mould by the time the second is being finished. As soon, therefore, as the floor becomes filled for a certain distance from the moulding table, the latter must be removed to a vacant spot, or the distance to which the bricks must be carried would be too great to allow of the boy's returning in time with the empty mould.

The moulding table is simply a rough table, made in various ways in different parts of the country. It is furnished with a water-trough, in which the moulds are dipped after each time of using.

In *pallet moulding* or *sand moulding* but one mould is used. Each brick, as it is moulded, is turned out on a pallet, and placed by a boy on a hack-barrow, which, when loaded, is wheeled away to the hack-ground, where the bricks are built up to dry in low walls called hacks. One moulder will keep two wheelers constantly employed, two barrows being always in work, whilst a third is being loaded at the moulding stool. When placed on the barrow, it is of comparatively little consequence whether the bricks have to be wheeled 5 yards or 50; and the distance from the moulding stool to the end of the hacks is sometimes considerable, but should never be so great as to require more than two wheelers.

In the table used for pallet moulding, for which the mould is usually sanded and not wetted, the water-trough is omitted, and a *page* (see Chap. III.) is added, on which the bricks are placed preparatory to their being shifted to the hack-barrow.

In some places, the operation of moulding partakes both of slop moulding and pallet moulding, the bricks being turned out on pallets and taken on barrows to the hack-ground, whilst the moulds are wetted as in the ordinary process of slop moulding.

*Brick moulds* are made in a variety of ways. Some are made of brass cast in four pieces and riveted together; some are of sheet iron, cased with wood on the two longest sides; and others again are made entirely of wood, and only the edges plated with iron. Drawings and detailed descriptions of each of these constructions are given in the subsequent chapters. In using wooden moulds the slop-moulding process is almost necessary, as the brick would not leave the sides of the mould unless it were very wet. Iron moulds are sanded, but not wetted. Brass, or, as they are technically called, "copper" moulds, require neither sanding nor wetting, do not rust, and are a great improvement on the common wooden mould formerly in general use, but are very heavy, expensive, and will not last long, as the edges become worn down so fast that the bricks made from the same mould at the beginning and end of a season are of a different thickness, and cannot be used together. This is a serious defect, and a metal mould which will not rust nor wear is still a great desideratum. It is essential that the sides of the mould should be sufficiently stiff not to *spring* when the clay is dashed into it, and it is equally requisite that it should not be made too heavy, or the taking-off boy would not be able to carry it to the floor. A common copper mould weighs about 4 lbs., and, with the wet brick in it, about 12 lbs., and this weight should not be exceeded.

There is a great difference in the quantity of bricks turned out in a given time by the pallet-moulding and by the slop-moulding processes. In slop-moulding 10,000 per week is a high average, whilst a pallet moulder will turn out 36,000 and upwards in the same period. This arises in a great measure from the circumstance that in pallet-moulding the moulder is assisted by a clot moulder, who prepares the clot for dashing into the mould; whilst in slop moulding the whole operation is conducted by the moulder alone.

The substitution of machinery for manual labour in the process of moulding has long been a favourite subject for the exercise of mechanical talent; but although a great number of inventions have been patented, there are very few of them that can be said to be thoroughly successful. The actual cost of moulding bears so small a proportion to the total cost of brickmaking, that in small brickworks where the raw material requires no grinding, the employment of machinery would effect no ultimate saving, and, therefore, it is not to be expected that machinery will ever be generally introduced merely for moulding bricks. In works situated near large towns, or in the execution of large engineering works, the case is very different, and a contractor who requires, say, 10,000,000 of bricks to be made in a limited time for the construction of a tunnel or a viaduct, can employ machinery with great advantage. For using shales and stony clays, machinery appears to be essential. A fuller description of brickmaking machines will be found in Chap. VIII.

A point of some little importance may be here mentioned, viz. is any advantage gained by forming a hollow or *frog* in the bed of the brick to form a key for the mortar? There are various opinions on this point, but we think it may be laid down as a principle, that if it is useful on one side it will be still better on both, so as to form a double key.

In London, where the brick mould is placed on a stock board, which is made to fit the bottom of the mould and the relative positions of the two are kept the same, no difficulty exists in forming a hollow on the bottom of the brick, this being effected by a *kick* fastened on the stock board. But this could not be done on the *upper* side, which is stricken level. In slop moulding, the mould is simply laid on the moulding stool, or on a moulding board much larger than the mould, and both sides of the brick are flush with the edges of the mould, no hollow being left, unless the moulder thinks fit to make one by scoring the brick with his fingers, which is sometimes done. When presses are used in moulding, it is equally easy to have a frog on one or both sides of the bricks.

*Presses* are used to a considerable extent for pressing bricks when partially dry, to improve their shape and to give them a smooth face (see Chapter VIII.). In some instances bricks so pressed *scale* on exposure to frost, and it is then better (though more costly) to dress the raw brick with a beater, as described in Chap. V. This pressing or dressing also corrects any twisting or warping which may have occurred during the earlier stage of drying.

*Ornamental bricks.*—The great practical difficulty in making moulded bricks for ornamental work is the warping and twisting to which all clay ware is subject in the process of burning. This difficulty is especially felt in making large articles, as wall copings, etc. In moulding goods of this kind it is usual to make perforations through the mass, to admit air to the inside, without which precaution it would be impossible to dry them thoroughly; for, although the outside would become hard, the inside would remain moist, and, on being subjected to the heat of the kiln, the steam would crack and burst the whole. On account of the difficulties experienced in manufacture, the production of large ornamental blocks is confined to the use of the less plastic clays, technically known as "terra-cotta clays," and some loams. Fireclays are usually admirable for this purpose if a red colour is not desired.

*Drying.*—The operation of drying the green bricks requires great care and attention, as much depends upon their condition when placed in the kiln. The great point to be aimed at is to protect them against sun, wind, rain, and frost, and to allow each brick to dry uniformly from the face to the centre.

Slop-moulded bricks are usually dried on flats or drying floors, where they remain from one day to five or six, according to the state of the weather. When spread out on the floor they may be sprinkled with sand, which absorbs superfluous moisture, and renders them less liable to be cracked by the sun's rays. After remaining on the floors until sufficiently hard to handle without injury, they are built up into hacks under cover, where they remain from one to three weeks, until ready for the kiln. In wet weather they are spread out on the floor of the drying shed, and great care must then be taken to avoid draughts, which would cause the bricks to dry faster on one side than the other. To prevent this, boards set edgeways are placed all round the shed to check the currents of air.

The area required for drying bricks in this manner is comparatively small, as they remain on the floors but a short time, and occupy little space when hacked in the hovels. The product of a single moulding stool by the slop-moulding process seldom exceeds 10,000 per week, and the area occupied by each stool is, therefore, small in proportion. Half an acre for each kiln may be considered ample allowance for the working floor and hovel.

Some bricks are not dried on flats, but are hacked at once on leaving the moulding stool, and remain in the hacks much longer. Thus, when pallet-moulding, a good man, with his assistants, will turn out from 30,000 to 40,000 bricks per week, and the clamps contain from 60,000 to 120,000 bricks and upwards. If the bricks are to be burned in a clamp, they are usually taken direct to the hack-ground, and several weeks must elapse before they are sufficiently dry to be used in the construction of the clamp. Bricks may be similarly dried on hacks and then burned in kilns.

From these combined causes, the area occupied by each stool is greater than in slop-moulded bricks, and it is not unusual for two or more acres to be required to dry the bricks made by each moulder.

The leading points on which depends the difference of area required for each moulder may be summarized as follows:—

| Slop-moulded bricks, hacked under cover, and burnt in kilns. | | Pallet-moulded sand stocks, burnt in clamps. |
|---|---|---|
| Dried one day on flats . . . | 1st | Hacked at once. |
| Closely stacked in hacks 17 courses high, placed close together under cover . . . | 2nd | Bricks loosely stacked in hacks, 8 courses high and 2 bricks wide, with 9 ft. spaces between the hacks |
| Remain in shed 10 to 16 days | 3rd | Remain in hacks 3 to 6 weeks. |
| Rate of production per stool, about 10,000 weekly . . | 4th | A gang will turn out 30,000 to 40,000 per week. |
| Kiln holds about 30,000 bricks, and may be fired once in 10 days . . . . . . | 5th | Clamp contains 60,000 to 120,000 bricks, and burns from 2 to 6 weeks |

In places where brickmaking is conducted on a large scale, the hacks are usually built in the open air, and protected from wet, frost, and excessive heat, by straw, reeds, matting, canvas screens, tarpaulins or wooden covers and side boards or "loos."

Where pressed facing bricks are made, and in many yards where bricks are made by machinery, drying sheds either in the form of steam or flue-heated floors (Fig. 36) or of "tunnel dryers" (Figs. 73 and 74) are used. The latter have a large output and are generally satisfactory when skilfully constructed, but require care and skill in use. For very small yards they are less used, and for works which are only open during the summer months the system of drying in hacks in the open air is still largely used.

As an instance of the care and attention required in drying some clays, it may be mentioned that many bricks will crack or even fall to pieces if the sun shines on them during the earlier stages of drying. Even in sheds and tunnel-dryers the greatest precautions must be taken to avoid draughts, and the application of too much or too sudden heat. Drying is, in fact, one of the most delicate problems which the brickmaker has to face when he is dealing with "tender" clays.

It is scarcely necessary to observe that different clays require different treatment, according to their composition, some bricks bearing exposure to sun and rain without injury, whilst others require to be carefully covered up to keep them from cracking under similar circumstances.

The bricks should be as dry as possible before they enter the kiln, or serious difficulties may arise. If they are to be clamp-burned, this dryness is even more important than when kilns are used. In the latter mode of burning, the heat can be regulated to great nicety, and if the green bricks, when first placed in the kiln, are not thoroughly dry, a gentle heat is applied until this is effected. In clamping, however, the full heat is attained almost immediately, and therefore the bricks must be thoroughly dried, or they would fly to pieces.

During drying, clays shrink—some of them very considerably. If this *contraction,* or *shrinkage,* is more than 1½in. for each foot of original length, some non-plastic material, such as sand, grog, chalk or "soil" must be added to reduce it to the above or a smaller amount.

*Burning*—Bricks are burned in *clamps* or in *kilns.* The latter is the common method, the former being only employed in burning bricks made with ashes or coal-dust. It should be observed, however, that the name of clamp is applied also to a pile of bricks arranged for burning in the ordinary way, and covered with a temporary casing of burned brick to retain the heat;

but this must not be confounded with close-clamping as practised in the neighbourhood of London.

The peculiarity of clamp burning is that each brick contains in itself the fuel necessary for its vitrification; the breeze or cinders serving only to ignite the lower tiers of bricks, from which the heat gradually spreads over the whole of the clamp. No spaces are left between the bricks, which are closely stacked, so that the heat to which they are exposed may be as uniform as possible. It is unnecessary here to go into the details of clamping, as they are very fully given in Chap. III.

A *kiln* is a chamber in which the green bricks are loosely stacked, with spaces between them for the passage of the heat, and baked by fires placed either in arched furnaces under the floor of the kiln, or in fire-holes formed in the side walls.

There are many ways of constructing kilns, and scarcely any two are exactly alike; but those used for bricks may be divided into five classes:—

1st. The common rectangular or "Scotch" kiln with fire-holes in the side walls. This is formed by building four walls enclosing a rectangular space, with a narrow doorway at each end, and narrow-arched openings in the side walls exactly opposite to each other. The bricks are introduced through the doorways, and loosely stacked with considerable art, the courses being crossed in a special manner, so as to leave continuous openings from top to bottom of the pile to distribute the heat. In the lower part of the kiln narrow flues are left, about 8 in. wide and about 2 ft. or 3 ft. high, connecting the fire-holes in the side walls. The kilns having been filled, the doorways are bricked up and plastered with clay to prevent the ingress of cold air; the top of the kiln is covered with old bricks, earth, or boards, to retain the heat, and the firing is carried on by burning coal in the fire-holes. A low shed is generally erected on each side of the kiln to protect the fuel and fireman from the weather, and to prevent the wind from urging the fires. The details of the management of the kiln are given in Chap. V., and need not be here repeated. This kind of kiln is the simplest that can well be adopted, and is the kiln in common use through the Midland and Northern counties, and in some parts of Scotland.

2nd. The rectangular kiln with arched furnaces or Newcastle kiln. This consists also of a rectangular chamber, but it differs from the first in having arched furnaces at one or both ends of the kiln.

The flue is at one end (if single fired) or in the centre (if double-fired), and connects to two short chimneys on top of the kiln or to a separate shaft by means of an underground flue. The fuel is sometimes fed through openings in the roof as well as into the ordinary fire-boxes (see illustration in Chap. VII.).

In a modification of this kiln, now seldom used, the fires are placed below the ground-level, and deliver their products into a flue beneath the kiln floor. This floor is formed like lattice-work, with numerous openings from the furnaces below, through which the heat ascends. The top of the kiln may be covered by a movable wooden roof, to retain the heat, and to protect the burning bricks from wind and rain, but this is seldom considered necessary. These kilns are largely used in the north-east of England.

3rd. The circular kiln and cupola. The former is domed over at the top (Fig. 50). The fire-holes are merely openings in the wall. If the latter are protected from the wind by a wall built round the kiln —which at the same time forms a chimney—and part of the dome is omitted, a cupola kiln is produced. These cupolas are used in Staffordshire and the neighbourhood, and the heat employed in them is very great. Drawings of a cupola are given in Chap. XIII., with an account of the manner in which the firing is conducted, and therefore it is unnecessary to describe any of these details here.

4th. The downdraught kiln (Chap. XIV.), is similar to the one just mentioned, except that the gases strike against the inside of the dome, are deflected downwards, and pass out through a central flue or "well" in the floor of the kiln. Such a kiln permits the production of the best qualities of facing bricks, but is somewhat costly in fuel as compared with chamber kilns on the "continuous" principle. For small yards making facing bricks, a rectangular or circular downdraught kiln is one of the most suitable that can be erected.

5th. The continuous kiln, in which a number of kilns or chambers are connected in such a manner that the heat from one passes into the next and so on until it is spent, when the gases are taken to the chimney.

In this manner bricks may be burned with one quarter to half of the fuel required by the kilns previously mentioned.

The object in using a continuous kiln is to utilize as nearly as possible all the heat produced from the fuel. In single kilns this is impossible, as the heat from the kiln is, for the most part, allowed to pass away up the chimney, and so is wasted, unless it is used in a waste heat dryer.

The continuous kiln was first introduced into this country by Friedrich Hoffmann, but many modifications of it still bear his name. To Hoffmann is undoubtedly due the credit of the greatest improvement ever made in the construction of brick-kilns, for his many successors and imitators, whilst improveing greatly on the structural arrangement of the kilns which bear their names, have, in every case, made use of Hoffmann's "continuous" principle, which is a special adaptation of Siemen's "regenerative heating" to the needs of the brick manufacturer.

The use of this kiln or one of its modifications has now spread to almost every part of the civilized world.

Fig. 1 is a half-plan on top of the kiln, the other half being a horizontal section at the level of the flues, leading into the central chimney-stack, as seen in the vertical section, Fig. 3. Fig. 2 is a diagram of the whole to a reduced scale, which is referred to in illustrating the description of the mode of working of the kiln. Fig. 3 is a vertical section.

The furnace or oven consists of a circular channel, O, of any section, which receives the objects to be fired, introduced through doors in the outside wall; the fuel is fed in by apertures formed in the top of the arch. Flues lead from the bed of the furnace to the smoke-chamber R, which surrounds the base of the central chimney, the communication with which can be cut off when required by means of cast-iron bell-shaped covers. An intercepting damper can be lowered or placed in grooves built into the walls of the furnace immediately behind each flue, so as to

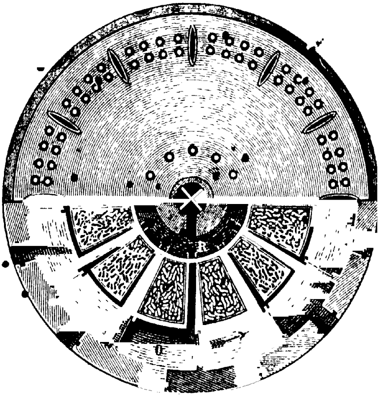

FIG. 1.—Plan of Hoffmann kiln.

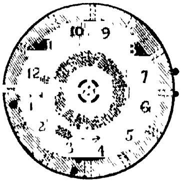

FIG. 2.—Diagram of continuous kiln.

separate it at any distinct or equidistant compartment. The fuel passes through apertures which are constructed in the arch, and falls through channels formed by the objects to be burnt to a chamber in the bed of the furnace, from which a certain number of small flues radiate to produce a free current from fire to fire. In practice it is found better to divide the kiln into twelve or more (imaginary) chambers, to which there are twelve entries or doorways, and the same number of flues communicating with the smoke-chamber, and just as many openings in the arch for the reception of the large intercepting dampers—thus the kiln can be divided at any one of the twelve parts. For clearer distinction, these compartments may be numbered, as in Fig. 2 from 1 to 12, of which two, Nos. 12 and 1, we will suppose are separated by the intercepting damper. Suppose the fire in full operation—the doors leading to the compartments 1

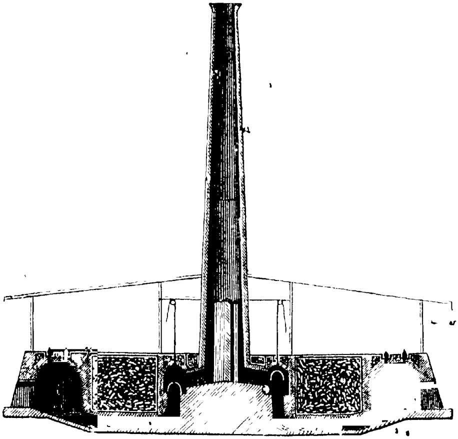

FIG. 3.—Vertical section of Hoffmann kiln.

and 2 being open, No. 1 for filling it with fresh goods, and No. 2 for taking out those already burned. The chambers Nos. 3, 4, 5, and 6, which are all filled with burned goods, are gradually cooling by the air entering through the doors of Nos. 1 and 2, and as it passes on through warmer and at last glowing ware, it will result that the kiln fires are supplied with atmospheric air almost as hot as the furnace itself. In chamber No. 7 the fire is burning, and when its contents have reached the desired temperature, No. 8 will have arrived at such a degree from the absorption of the waste heat, that the fuel introduced from the top is instantly inflamed.

The compartments Nos. 9, 10, 11, and 12 will be dried off and heated one after another by the waste heat which passes through and expends itself on the contents of these chambers, and on its arrival in No. 12, meeting with the obstruction of the large damper, it is conducted by the small flue to the chimney, with its temperature again so lowered that it will only just support the draught. No. 1 being now filled again and its doorway tightly closed, the damper between 12 and 1 is lifted and lowered between 1 and 2. The bell damper above the mouth of the flue No. 12 is lowered, and that of No. 1 lifted. The doorway of compartment No. 3 is opened, as its contents will be sufficiently cooled to be taken out, while No. 2, which is empty, can be filled again.

In 1864 Professor J. Thomson, of Belfast, read a paper on the manufacture of bricks, before the Chemico-Agricultural Society of Ulster, in which he referred at considerable length to the Hoffmann kiln. The following is an abstract of his paper:—Having explained the chief methods in use for working the clay and forming it into bricks ready for the kiln, the author turned attention to the loss of heat which occurs in the ordinary modes of burning bricks in common kilns. This loss is twofold. First, during the burning of the bricks the air which has passed through the fuel, or among the heated bricks, and the smoke, including the gaseous products generally, pass away from the kiln to waste at a very high temperature, even at a red heat, during a considerable part of the process. Secondly, when the bricks are raised to the high temperature required to burn them, and render them permanently hard, the great store of heat which they contain is entirely thrown to waste while they are left to cool. In this new kiln a remarkable economy of fuel is effected, by saving the twofold loss of heat already mentioned: first, it saves the heat of the gaseous products of combustion and unconsumed air passing through and away from the burning bricks, by applying this heat effectively in drying the new fresh bricks about to be burned, and raising them up to an incandescent temperature, so that only a very slight addition of heat from ignited fuel is required to complete their burning; and, secondly, it saves the heat of the cooling bricks, after their having been sufficiently fired, by applying it all again in warming the air which goes forward to supply the fires; so that the fuel is burnt with air already at nearly an incandescent temperature, instead of requiring, as usual, to heat the air for its own combustion. Professor Thomson described, as an example, the large kiln at Hayfield Park, near Belfast. The kiln was built in the form of a large arched passage, like a railway tunnel, bending round in going forward on the ground till it closes with itself to form a great circular ring-chamber, within which the burning of the bricks is carried on. This ring-chamber may be of any convenient dimensions, 160 ft. diameter being a suitable size. Round its circumference there are twenty-four entrance doorways, admitting of being closed with temporarily built bricks and clay, so as to retain the heat and exclude all entrance of air by the doorways so built up. The great ring-chamber may now be conceived as consisting of twenty-four compartments or spaces, with one of these doorways to each. In the centre of the ring a high chimney is erected, and from each of the twenty-four compartments of the annular chamber an underground flue leads into the chimney. There are, then, twenty-four of these flues converging towards the centre like the spokes of a wheel, and each flue has a valve, by which its communication with the chimney can be cut off. Arrangements are made by which a partition like a damper can be let down at pleasure, or otherwise placed, so as to cut off all communication between any of the twenty-four compartments of the ring-kiln and the next one. Let us now suppose the working of the kiln to have been already fairly established; for, after being once kindled, the fire is never extinguished, but the burning of new bricks and the removal of the finished product are carried on by a continuous and regular process from day to day. Two adjacent compartments have this day their entrance doors open, all the rest being perfectly closed. By the arrangement of the valves in the flues, and the large partition, the air which gets admittance alone by the two open doors has to go round the whole circuit of the ring-kiln in order to be drawn into the chimney. From one of the two open compartments men are taking out the finished and cooled bricks, and in the other one they are building up newly formed unburned bricks which are not yet quite dry. The air, entering by these two compartments, passes first among bricks almost cold and takes up their heat, and then goes forward to warmer bricks, and then to hotter and hotter, always carrying the heat of the cooling bricks forward with it till it reaches the part of the ring diametrically opposite to the two open and cold compartments. At this place it gets a final accession of heat from the burning of a very small quantity of small coal, which is dropped in among the bricks from time to time by numerous small openings furnished with air-tight movable lids. Thus at this part of the kiln there is generated the full intensity of heat which is required for the burning of the bricks. The hot air, including the products of combustion, which, for brevity, we may call the smoke, though it is really perfectly gaseous and free from sooty particles, then passes forward to the bricks, which, by its continuous current, are being heated; and it passes on among them from hot bricks to those which are less and less hot, heating them as it goes, and then passes on to those which are still damp, drying them as it goes; and then it passes to the chimney, in a state almost cold, and saturated with the moisture, in the form of steam or vapour, which it has taken from the damp bricks. On the following day to that on which the operations just described have been going on, the partition is shifted forwards by the space of one compartment, and a corresponding change is made as to the flue which is to communicate with the chimney, and as to the pair of compartments open for the admission of air and for the removal of finished cold bricks, and the building in of fresh damp bricks; and so the air, including the products of combustion, at the end of its circuit in the annular chamber, just before passing off to the chimney, now passes among the fresh bricks which were described as built in on the yesterday of this new day. The place where the small-coal fuel is thrown in is also advanced round the circle by the stage of one compartment; and so now the whole process goes on just as it did "yesterday." The fire thus makes a complete circuit of the annular chamber in twenty-four working days. The whole process may be left dormant on Sundays, merely by the closing of all apertures for the admission of the current of air. The same kind of kiln, with the same process of working, is applicable in the burning of lime; and both for the brick-burning and the lime-burning, the saving of fuel, relatively to what is consumed by the ordinary methods, is such as to appear at first sight almost incredible.

The original Hoffmann kilns were circular, but most of the modern ones are in the form of a rectangle and semicircular ends (Fig. 4). Some of the still more recent patterns consist of two rows of chambers placed back to back and are almost perfectly rectangular in plan. The most recent continuous kiln is almost square in the external plan, the "tunnel" being bent backwards and forwards on itself in a remarkable manner so as to form an exceedingly compact kiln.

The original Hoffmann kiln had no permanent partitions, but for burning facing bricks, terra-cotta, etc., it is found to be advantageous to use permanent partitions of brickwork and to burn the fuel on grates instead of amongst the goods. The slight additional amount of fuel burned is compensated by the improved colour of the goods.

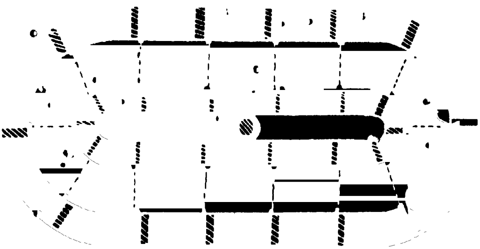

FIG. 4.—Sectional plan of modern continuous kiln.

A complete description of the different types of continuous kilns now in use in this country would occupy a volume much larger than the present one. Some of their main characteristics are mentioned in "Modern Brickmaking." Further details can be obtained by a study of the advertisements in the various trade papers, or on application to their editors. It should, however, be remembered that not all patent continuous kilns are equally valuable. As no one kiln can be used satisfactorily for every kind of bricks, it is always necessary to exercise the greatest care to avoid making serious errors in the choice of a kiln.

For satisfactory working, a continuous kiln should have an average output of *at least* a chamber a day or six chambers per week. For lesser outputs the difficulties in working are considerably increased. So that where the output is not sufficient for a complete continuous kiln—for this type of kiln is not suitable for very small or irregular outputs—a *semi-continuous kiln* may be erected. This is really a portion of a continuous kiln, but instead of working in continuous manner, the heating is started at one end and is continued until the bricks at the other end are burned. The kiln is then allowed to cool, and is completely emptied before being restarted. The advantage of the semi-continuous kiln over single, intermittent ones is a considerable saving in fuel (though not so great as in a complete continuous kiln) and if it is designed to form part of a continuous kiln, the latter may be completed whenever the output justifies it.

When a kiln has been in use for a short time it will need a certain amount of repairs, and if not maintained in good condition will rapidly deteriorate. Hence it is unwise to cut down the original cost of erection to such a point that good construction becomes impossible, for a badly erected kiln is a perpetual source of anxiety and expense.

The *site* on which a kiln is erected is highly important; if the ground is badly drained or is damp, the moisture will rise during the time the kiln is being heated and will cause a considerable amount of damage to the bricks being burned. If a kiln must be erected on a damp site which does not permit of drainage, a special foundation should be constructed.

The usual method of *placing* bricks in a kiln is to cross them, leaving spaces for the passage of the heat, but there are objections to this, as many bricks show a different colour, where they have been most exposed to the heat. Thus in many parts of the country, the bricks exhibit a stripe of a lighter tint than the body of the brick, which shows the portion that has been most exposed. In burning bricks that require to be of even colour, this is guarded against by placing them exactly on each other.

On first lighting a kiln the heat is applied very gently, so that the moisture in the bricks may be gradually evaporated ("water smoking").

The bricks are then thoroughly "dried," which is known by the steam ceasing to rise, or more accurately by inserting a cold, polished steel bar (poker) into the kiln, withdrawing it after a few seconds and noticing whether there is any moisture condensed on it. If no deposit is formed the bricks may be considered to be dry. After this the fires are increased, and in the case of an open kiln the top is covered with turf, old bricks, soil or ashes to retain the heat.

As the heat increases, the mouths of the kiln are stopped to check the draft, and when the burning is completed, all openings are plastered over to exclude the air, and the fires are allowed to go out. After this the kiln is, or should be, allowed to cool very gradually, as the soundness of the bricks is much injured by opening the kiln too soon.

*Fuel.*—Pit coal is the fuel commonly used, and the quantity required is 7 to 12 cwt. per 1000 bricks for a single kiln of the Scotch, Newcastle or Down-draught kilns, or 3 to 5 cwt. per 1000 bricks in a continuous kiln. These figures are sometimes largely exceeded, for much depends on the quality of the coal, the construction of the kiln, the clay and the skill with which the bricks are stacked.

Wood is sometimes used as fuel in the preliminary stage of firing, but not to a great extent.

*Shrinkage.*—During the burning, the clay shrinks still further, and, losing its plasticity, becomes rigid and stonelike. The temperature required to do this and to produce good, sound bricks depends upon the clay itself and the manner in which it is manipulated.

The shrinkage depends, to some extent, on the proportion of "true clay" in the material, and on the proportion of free silica present, as the latter expands on heating.

During the burning partial fusion occurs, the molten material, on cooling, solidifies and cements the remaining particles into a strong mass. The extent to which this fusion is allowed to occur depends on the purposes for which the bricks are to be used.

If the temperature rises too rapidly the bricks may become discoloured, frequently showing a black "core" or "heart" when broken, or the fusion may occur so extensively that the bricks may swell, twist, or even lose their shape through collapse.

The foregoing sketch of the chief operations of brickmaking and some of the principles on which they depend is necessarily brief. It need hardly be said that the illustrations might be greatly extended, as there are scarcely two counties in England in which the processes are exactly similar, but this would lead far beyond the limits of a Rudimentary Treatise, and enough is given to show the student the intrinsic interest of the subject, and to enable him to study larger books on Clayworking and Ceramics, and to think and examine for himself. If he be induced to do this from the perusal of these pages, the aim of this little volume will have been completely fulfilled.

# CHAPTER III.

## HAND BRICKMAKING IN THE VICINITY OF THE LONDON AND HAMPSHIRE BASINS.

An important brickmaking area extends over a large part of Essex, Kent, Middlesex and westward to Hampshire. This area consists of two distinct portions shown on geological maps as the London and Hampshire Basins. Brickmaking is, in fact, carried on to a great extent all round the metropolis, but the principal brickfields are situated north of the Thames.

Special methods of manufacture are used in these districts, the materials being different to those employed for brickmaking in other parts of the country.

The chief characteristic of this kind of brick is due to the use of dust sifted from breeze (p. 67), which is thoroughly incorporated with the brick earth in the pug-mill, so that each brick becomes a kind of fire ball, and contains in itself the fuel required for its vitrification. In building the clamps the bricks are stacked close together, and not as in ordinary kiln-burning, in which openings are left between the bricks to allow of the distribution of the heat from the live holes. The effect of these arrangements is to produce a steady uniform heat, which vitrifies the bricks without melting them. Those bricks which are in contact with the live holes or flues melt into a greenish-black slag.

## 1. MATERIALS.

1st. *Brick-earth.*—The brickmakers in the vicinity of London derive their principal supplies of brick-earth from the alluvial deposits lying above the London Clay, the blue clay not being used for brickmaking at the present day. The general character of the brick-earth may be described as being a gravelly loam, passing by fine gradations into either a strong clay or into marl, or, as it is technically called, malm—an earth containing a considerable quantity of chalk in fine particles. It is convenient to classify the several qualities of brick-earth under three heads: strong clay, loam, and malm, though this classification, whilst best understood by the generality of readers, would not be used by most brickmakers, who class these three qualities of brick-earths as strong clay, mild clay, and malm. When the clays are strong, they are said, in brickmaker's language, to be *foul*.

*Strong Clay.*—This is generally sufficiently free from stones to be used without washing, and the bricks made from it are hard and sound, but are liable to crack and contract very considerably in drying, and to become warped and misshapen in burning. These defects are in a great measure removed by mixing the earth with chalk, reduced to the consistency of cream in a wash-mill. This effects a triple purpose, for the chalk not only imparts soundness to the bricks, acting mechanically to reduce the shrinkage and cracking of the clay, but in the second place it acts chemically, as a flux during the burning, combining with the silica of the clay, so that a well-burned London brick may be considered to contain a cement made of silicate of lime and alumina, binding the other particles together. When present in sufficient quantity, chalk corrects the evil effects of an overdose of sand, as it takes up the excess of silica that would otherwise remain in an uncombined state. Thirdly, and most important of all, it greatly improves the colour of the bricks.

*Loam.*—The loams are often so full of gravel that it is impossible to free them from stones, except by passing the earth through the wash-mill, but are otherwise valuable. The quantity of sand present in these earths renders them less liable to shrink and warp than the strong clays; but, on the other hand, the texture of some of them is so loose and incoherent, that a mixture of chalk is necessary to bind the mass together, and to bind the silica in the process of burning.

*Malm.*—This is an earth suitable for making London bricks, without any addition, but there is very little now obtainable, and for making the best qualities of London bricks an artificial malm is made by mixing together chalk and clay, previously reduced to slip in wash-mills. This slip is run off into shallow pits, where it remains until, by evaporation and settlement, it has become of sufficient consistency for subsequent operations. This process is adopted for the best qualities of bricks only, as the expense of it is very considerable; and, for the commoner sorts, all that is done is to mix with the loam or clay a sufficient quantity of malm to make it suitable for brickmaking: the quantity of malm required for this purpose varies, of course, according to the quality of the earth.

It will be readily understood, from the above remarks, that the mode of preparing the clay differs greatly in different yards. The brick-earth (according to its quality) being used—

(*a*) Without either washing or malming; (*b*) it may be malmed, *i.e.* covered with artificial malm; and (*c*) the bricks may be made entirely of malm.

The second process is the most common, and on page 89 the successive operations of brickmaking, as practised at those works where the loamy character of the earth renders the malming indispensable, are described. This will enable the reader to understand the first and third methods of treating the brick-earth without any further description.

2nd. *Soil.**—The process of malming is not the only peculiarity of "London" brickmaking. Instead of the bricks being burned in close kilns, as is the practice in most country yards, "clamping" is universally used; and to render this effective, it is considered necessary that the fuel should be mixed with the brick-earth so that each brick forms, as it were, a fire-ball, and becomes thoroughly *burned* throughout, instead of being merely *baked*, as is the case of much kiln burning. The fuel used in clamp burning is domestic ashes. The ashes are collected in large heaps, and sifted; the siftings, or dust, which are called *soil*, being mixed with the brick-earth, and thoroughly incorporated with it in the processes of "soiling" and "tempering," whilst the coarser cinders, or "breeze," are used as fuel. A small quantity of coal and wood is also used in lighting the clamp.

The soil, or sifted ashes, materially assists in preventing the contraction of the raw bricks whilst drying, and the sulphur contained therein appears to assist in colouring the bricks when burned.

If the "London method" of brickmaking is used in other districts great care is required, or disastrous results may ensue. Thus, *coal dust* is used in some districts instead of ashes, and provided an undue proportion is employed, a whole clamp of bricks may be destroyed by overheating. A case of this sort occurred many years ago at Lampeter, in Wales, where an Islington brickmaker was sent, and "being too conceited to make inquiries or to receive information, he set light to a clamp he had prepared with coal, containing 70,700 bricks; and in a very short time the whole kiln was in one general blaze. The man was alarmed and took to his heels, and, unlike Lot's wife, he turned not back, neither looked behind him. Even from the heights leading to Landovery the *reflection* was quite enough for him; nor did he stop till he reached London, being, as he said, afeared they would catch him and put him in prison!"

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* Soil, *i.e. ashes*, must not be confounded with soil, *vegetable mould*, which is in some places mixed with strong clay, to render it milder.

Other cases, less dramatic but no less disastrous, have occurred since in other districts.

3rd. *Breeze.*—This is a casual mixture of cinders, small coal and ashes, such as is collected by dustmen, from which the finer portion has been removed by sifting. Its chief use is to produce sufficient heat to ignite the powdered fuel ("soil") mixed with the clay of which the bricks are made. For this purpose the cinders or breeze is distributed in layers between the courses of bricks, the strata of breeze being thickest at the bottom.

The quantity of breeze required varies much with the quality of the earth. The usual proportions for every 100,000 bricks are about 35 chaldrons of the sifted ashes, mixed with the brick-earth, and about 12 chaldrons of the cinders or breeze to light the clamp.

The quantity of fuel to the live holes (Fig. 22) is difficult to calculate; about 2*s.* may be taken as the average cost of coals and wood for every 100,000 bricks.

If the proportion of breeze be too small, the bricks will be underburned, and will be tender and of a pale colour. If too much fuel be used, there is danger of the bricks fusing and running into a blackish slag. No rules can be laid down for avoiding these errors, as the management of the breeze must depend upon the quality of the earth, and can only be learnt from experience, some brick-earths being much more fusible than others.

4th. *Sand.*—The sand used for moulding London bricks is generally obtained from the Thames, near Woolwich, but other (local) sands are frequently used. This sand serves many useful purposes. It assists in preventing the contraction of the clay, and gives a more durable surface to the bricks. It is indispensable to the moulder for preventing the bricks from sticking to the mould. It also prevents the bricks from sticking together on the hacks, and from breaking up into "cracks" and "flaws" when cooling, after being burned. Lastly, the salt in the river sand becomes decomposed in the burning, and assists in fluxing the brick-earth, and in giving the bricks their colour. Sand which burns of a red tint, and so would injure the colour, cannot be used for London stock bricks. In some other parts of the country a red burning sand is largely employed.

As the sand must be quite dry before it can be used, it is spread out to dry in the sun in thin layers, which are repeatedly raked over, so as to expose every particle in succession to the sun's rays. Some brickmakers spread the sand on the floor of a small kiln, if one is available, but this method of drying is seldom advisable.

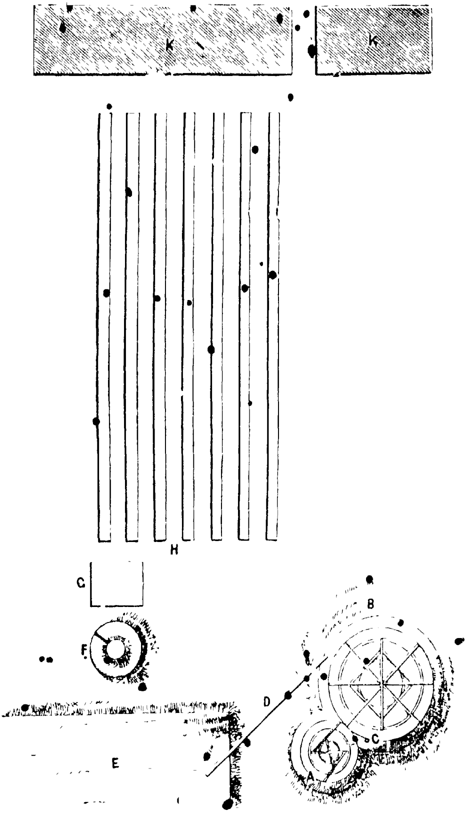

FIG. 5.—General plan of a brickwork. Scale 40 ft. to an inch.

| | | | |
|---|---|---|---|
| A. | The chalk-mill. | F. | The pug-mill. |
| B. | The clay-washing mill. | G. | The moulding stool. |
| C. | The pump. | H. | The back ground. |
| D. | The trough to the brick-earth. | K.K. | Clamps. |
| E. | Brick-earth ready to receive malm. | | |

## 2. PLANT.

The *General Arrangement of a Brickwork* will be readily understood by reference to Fig. 5. The brick-earth is spread so as to receive the malm. The clay-mill (B) and chalk-mill (A) are placed close together in some convenient position, and the malm is conveyed from them to the heap of brick-earth (E), by means of troughs (D), supported on tressels. Close to the brick-earth, and immediately behind the moulding stool (G), is placed the pug-mill (F), and in front of the moulding stool is the hack-ground (H), which should, if possible, be laid with a gentle fall towards the clamps, which are placed at its furthest extremity. These arrangements are, of course, much modified by the circumstances of the locality.

*The Wash-mills.*—The wash-mills are placed close together on a large double mound, sufficiently elevated to allow the malm to run down freely to the brick-earth.

In them the material, with a sufficient amount of water, is converted into a cream or *slurry.*

The average output of horse-driven wash-mills working 10 hours a day, may be taken at about 12 cubic yards of malm, or sufficient for making 6000 malm bricks. Power-driven mills have a somewhat larger output. No drivers are required for horse-driven mills.

The *clay-mill* consists of a circular trough, lined with brickwork, and in this trough the clay is mixed with the pulp from the chalk-mill, and is cut and stirred by knives and harrows put in motion by two horses or by mechanical power, until the whole mass

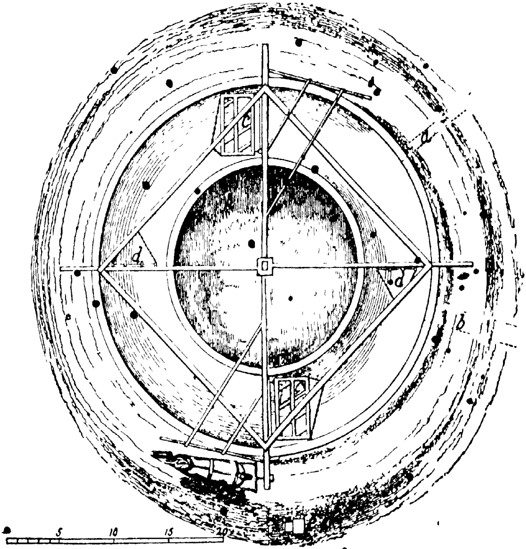

FIG. 6.—Plan of clay-washing mill.

*a.* Inlet from the chalk-mill. *b.* Outlet to the shoot.
*c.c.* Harrows. *d.d.* Cutters. *e.* Pump.

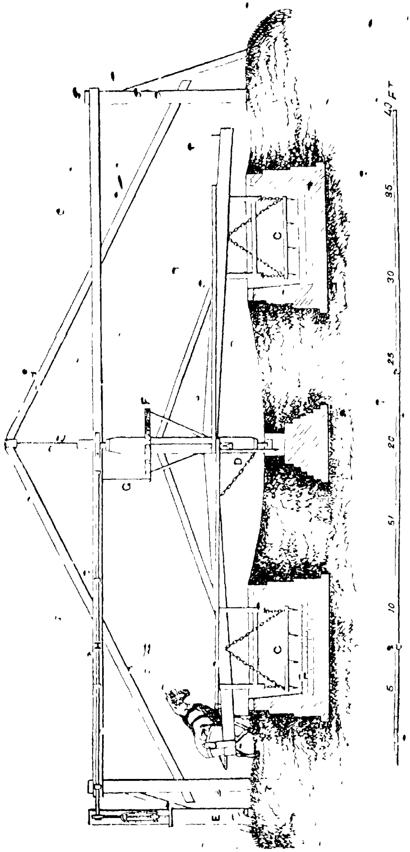

FIG. 7 —Sectional elevation of clay-mill.

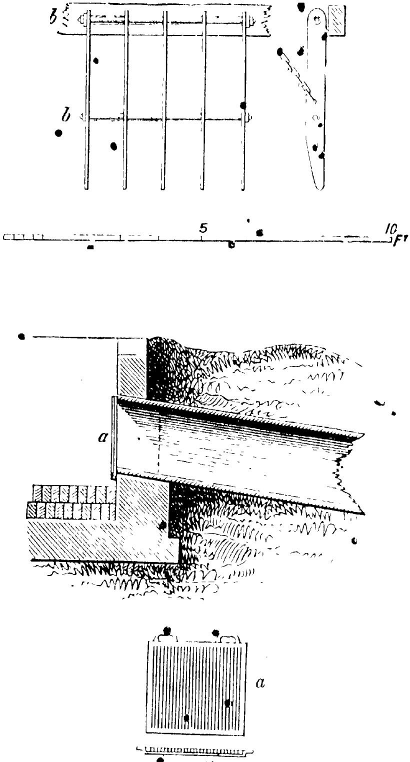

Fig. 8.—Parts of clay-washing mill.
*a.* Grating and outlet of mill.
*b.* Knives or cutters.

is reduced to the consistency of cream, when it passes through a brass grating (Fig. 8) into the trough and is conducted to the brick-earth which has been spread and heaped to receive it. The framework of this mill is very simple, and need not be described in detail as its construction is clearly shown in Figs. 6–8.

The knives, or cutters, (*d d*), are placed in two sets, four in each. They are fixed in an upright position, and steadied to their work by chains, and by being bolted together with bolts passing through tubular distance pieces, as shown in Fig. 8. The knives cut the clay and clear the way for the harrows, (*c c*) which are similar to those used for agricultural purposes, and are merely suspended by chains from the timber framing. The pump (*e*) is worked by the horizontal wheel (F), Fig. 7, which is provided with friction rollers on its rim, for the purpose of lifting the lever (G), which raises the lever of the pump by means of the spindle (H). The outlet to the shoots is simply a square trough made of 2 in. planks. It is furnished with a brass grating, or strainer, shown in Fig. 8. The bars are $\frac{3}{4}$ in. wide and $\frac{1}{4}$ in. apart, so that even small stones will not pass through. This grating is fixed in grooves, so that it can be lifted out of its place by the handles, when required. To keep the clay-mill in full work 4 diggers and 2 wheelers are required.

The *chalk-mill* (Figs. 9 and 10) is much smaller than the clay-mill, but, like it, is a circular trough lined with brickwork and partly filled with water. The chalk is ground by the action of two heavy wheels with spiked tires, made to revolve by either one or two horses or by mechanical power. The

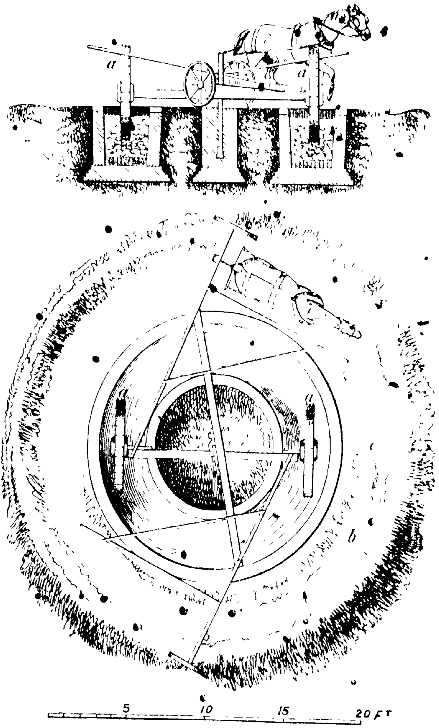

FIG. 9.—Section and plan of chalk-mill.

*a.a.* Grinding-wheels. *b.* Inlet from pump.
*c.* Outlet to clay-washing mill.

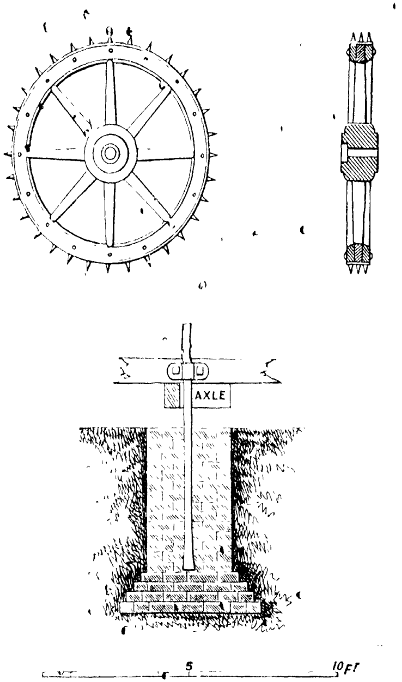

Fig. 10.—Details of chalk-mill, showing grinding wheel (front view and section), and mode of connecting axle-tree of grinding wheels to the centre shaft.

trough is supplied with water by a pump, the lever of which is worked by the machinery of the clay-mill, and as the chalk becomes ground into slurry it passes, by means of a shoot or trough, into the clay-mill. The construction of one of these wheels is shown in detail in Fig. 10. It is necessary that they should accommodate themselves to the level of the chalk in the trough, and to effect this, the framing of which the axle-tree forms a part, is secured to the centre shaft by a staple, as shown in Fig. 10, which allows the whole of the timbering to rise or fall, as may be requisite. The centre shaft is a bar of iron steadied by being built up in a mass of brickwork. The yoke beams are kept at the proper height and their weight supported by common light chaise wheels, about 2 ft. 6 in. diameter, which run on the outside of the horse track. The mill represented in these engravings is mounted for two horses; many chalk-mills, however, have but one, though two are necessary for most clay-mills.

To keep a chalk-mill in full work 2 diggers and 1 wheeler are required.

At the present time the primitive horse-driven wash-mill has been, in many instances, replaced by a similar mill driven by a portable engine. This is more regular, more powerful, and at the same time more economical, as a horse is far from satisfactory as a source of motive power. The construction of the mills are not materially altered by this change, the most noticeable difference being a greater compactness of the framework, a simple pulley on top of the central shaft taking the place of the long beams. An excellent description of a wash-mill of this description

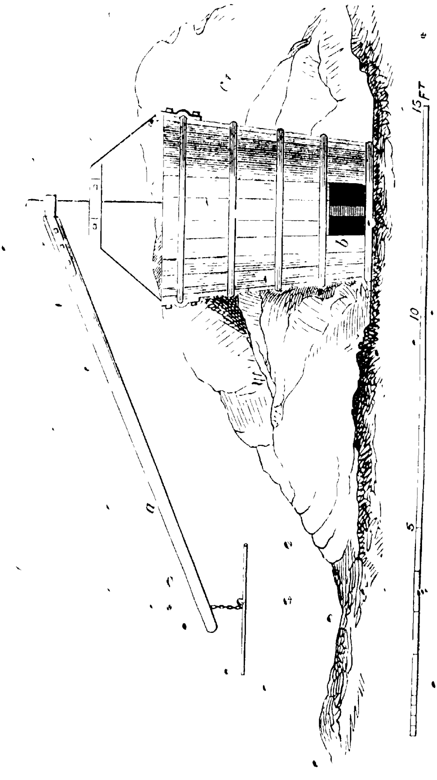

FIG. 11.—Elevation of pug-mill.

*a.* The yoke arm. *b.* The ejectment opening.
*c.* The brick-earth surrounding the mill, on which is an inclined barrow road to the top of the mill.

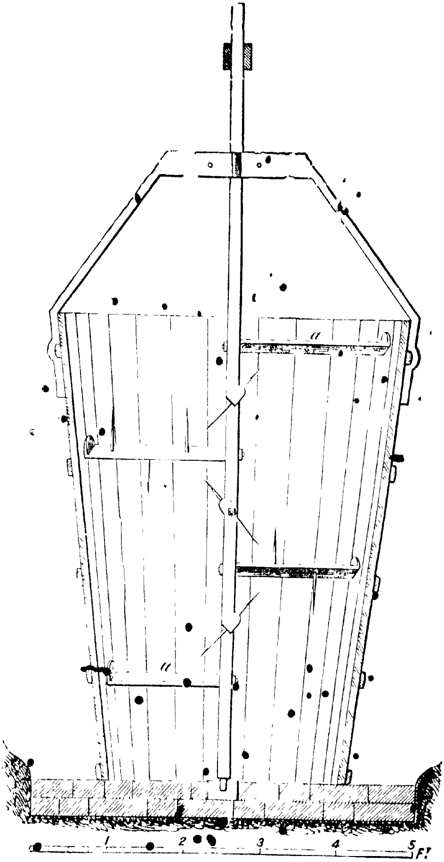

FIG. 12.—Section of pug-mill.

*a.a.* Force knives. These are not provided with cross knives, like the others, their purpose being merely to force the earth downwards and out at the ejectment hole.

was given in the "British Clayworker" for April, 1901, page 10.

The mechanical parts of power-driven wash-mills are supplied, ready for use, by several firms of brick-machinery makers.

*The pug-mill* used in brick-making is a conical tub (Fig. 11), with its larger end uppermost, in the centre of which is a revolving vertical shaft of iron to which are attached horizontal knives, inclined so that the clay is slowly forced downwards by their motion. It may be made of either wood or metal, but must be very strong. The top and bottom knives are called *force knives*, and their use is merely to force the earth through the mill and out at the ejectment hole; all the other knives are furnished with cross knives, which assist in cutting the clay, and breaking up any hard lumps that may not have

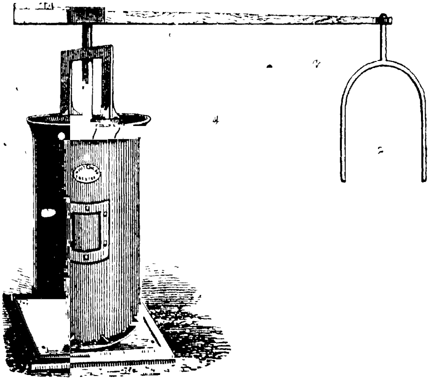

FIG. 13.—Horse-driven, iron-cased pug-mill.

been broken up by the previous wintering and turning over. In order to feed the mill, an inclined barrow-run may be laid up to it, to enable the wheeler to tip the clay in at the top.

The construction of a pug-mill is shown in Figs. 11, 12, and 13.

The last-named is particularly large and powerful for a horse-driven pug-mill. The cylinder is a strong casting, on a massive iron basement, and provided with two cast mouth-pieces for the discharge of the pugged clay, one on each side at the bottom. These mouth-pieces may have sliding doors fitted, to increase or diminish the area of the orifice, so as to cause the clay to be more or less pugged. This is valuable in adapting the mill to pressing small pipes, etc.

This mill makes about three revolutions per minute, when worked by the power of one horse. The cylinder is 24 in. diameter inside, and 54 in. high; the total height to top of the vertical shaft is 87 in.

Much better results may be obtained from pug-mills driven by mechanical power, as those operated by a horse can only give so slight a treatment. In a mechanically driven mill the knives are broader and stronger, and mix the material much more thoroughly.

When engine-driven pug-mills are used it is not unusual for them to be horizontal instead of vertical. (See Chap. VIII.)

*The Cuckhold* (*o* in Fig. 14) is an instrument for cutting off lumps of tempered clay as it is ejected from the pug-mill. Its shape and construction are shown clearly in the illustration, so that it requires no particular description.

*The Moulding Stool* (Fig. 14) is quite different from that used in most parts of the country. It has a rim at each end, to keep the moulding sand from falling off, and is provided with a *stock board* (which forms the bottom of the brick mould), and with a *page*, which is formed of two rods of $\frac{3}{8}$ in. iron, nailed down at each end to the wooden rails on which they rest. The use of the page is to slide the raw bricks more readily from the moulder to a convenient place from whence they are put on a hack barrow by the "taking-off" boy. The moulder, when at work, stands near the middle of the stool, with the page on his left hand, and his assistant, the clot-moulder, on his right. The moulding sand for the use of the moulder and clot-moulder is placed in separate heaps at the opposite ends of the stool, and the tempered clay nearly opposite to the moulder. There is no water-box, but a tub is placed on the stool, into which the strike is thrown when not in use. The pallets are placed at one end of the page, and close to the moulder's left hand. These particulars will be fully understood by reference to Fig. 14.

*The Brick Mould* (Fig. 15) is made of sheet iron, in four pieces, riveted together at the angles, and strengthened with wood at the sides only. The bottom of the mould is detached, and forms the *stock board*.

*The Stock board* is a piece of wood plated with iron round the upper edge, and made to fit the mould accurately, but easily. At each corner an iron pin (*a*, Fig. 15) is driven into the moulding stool, and on these pins the bottom of the mould rests, the thickness of the brick being regulated by the distance to

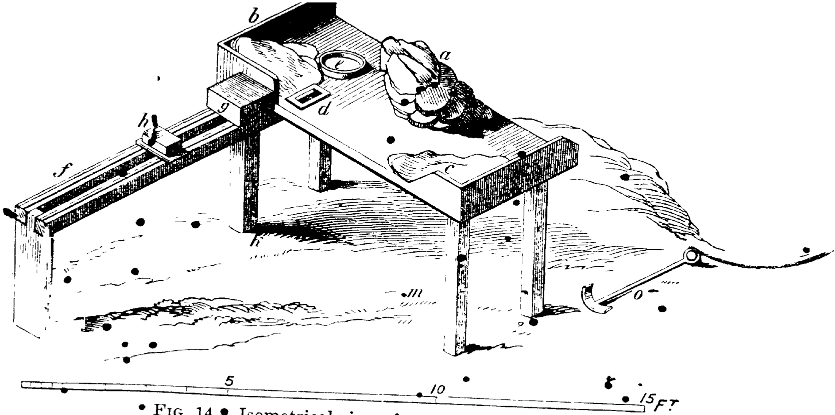

FIG. 14.—Isometrical view of moulding stool.

*a.* Earth from the pug mill.
*b.* Moulder's sand.
*c.* Clot-moulder's sand.
*d.* Bottom of the mould, or *stock board.*
*e.* Water-tub.
*f.* *Page.*
*g.* Pallets in proper position for use,
*h.* A newly-made brick ready for taking-off.
*k.* Moulder's place.
*m.* Clot-moulder's place.
*n.* Taking-off boy's place.
*o.* *Cuckhold.*

which the pins are driven below the top of the stock board. The hollow in the bed of the brick is produced by a rectangular piece of wood, called a *kick*,

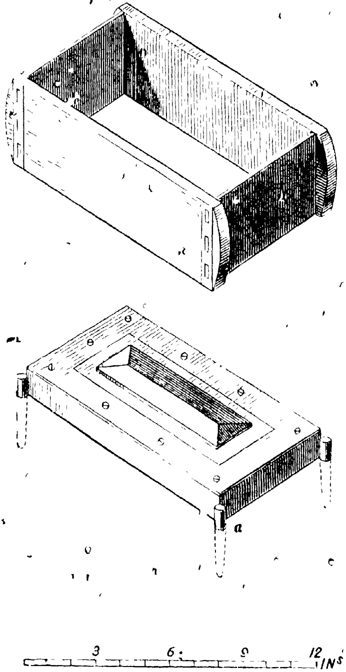

FIG. 15.—Isometrical view of brick mould, with its detached bottom or stock board.

of the size and shape of the hollow required, which is fastened on the upper side of the stock board.

*The Strike* is a smooth piece of wood about 10 in.

long by 1½ in. wide and ½ in. thick, which is used to remove the superfluous clay from the mould.

*The Pallets* are pieces of board ⅜ in. thick, and of the exact width of the mould, but about ¾ in. longer. Three sets of pallets, twenty-six in each set, are required for each moulder.

*The Hack Barrow*, Figs. 16 and 17, is of a peculiar construction. It consists of a light frame, supporting a flat top of latticework, on which the bricks are placed in two parallel rows, thirteen in each row. Three of these "off-bearing" barrows are required to each moulder.

The proportions of the barrow are important; it must be skilfully made so as to be well balanced and not require any unnecessary energy to drive.

There should be some arrangement of steel springs or rubber to prevent the bricks being jarred and damaged in transit. For many purposes bow-springs are the most satisfactory and durable; rubber cushions are good, but soon become hard and useless.

*The Hack Ground* occupies the space between the moulding stool and the clamp. It should be well drained, and it is desirable that it should be on a slight fall towards the clamp as this lessens the labour of wheeling. The foundations of the hacks are slightly raised. It is of importance that the barrow-runs between the hacks should be perfectly even, as any jolting of the hack barrow would injure the shape of the raw bricks, which, when first turned out of the mould, are very soft. For this reason long strips of iron are sometimes laid on the ground. The hacks are placed 11 ft. apart, measured from centre

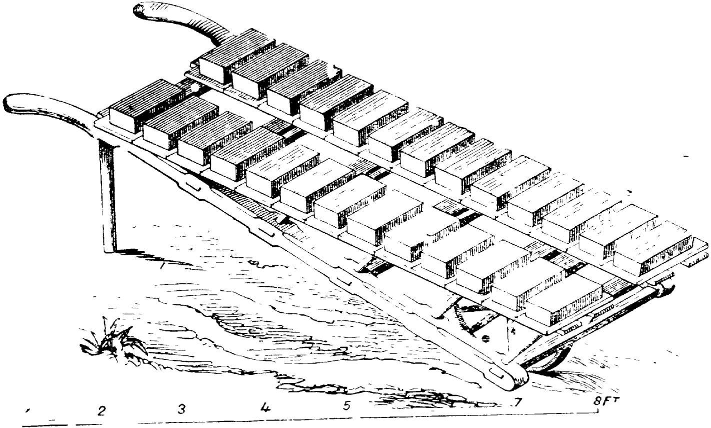

FIG. 16.—The hack or off-bearing barrow—loaded.

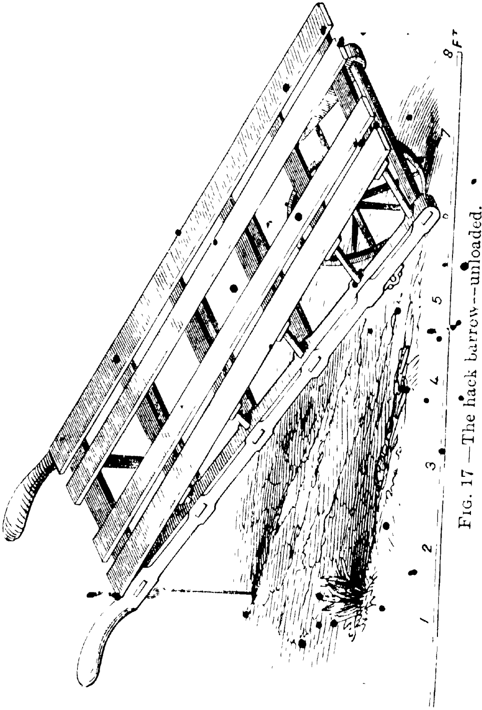

FIG. 17.—The hack barrow—unloaded.

to centre, their length varying according to the shape of the ground (see p. 69).

It is very difficult to say what extent of hack ground should be allotted to each moulding stool, as this varies greatly in different yards. In round figures, the quantity of land required may be stated as from 1½ to 2 acres for each moulder, but this includes the whole of the land required for the several purposes.

### 3. PROCESS OF MANUFACTURE.

*Clay Digging.*—The first turning over of the brick-earth should take place in the autumn, in order that it may have the benefit of the winter frosts before being used. The vegetable mould and top soil having been wheeled out of the way, the brick earth is turned up three or four spits * deep, and laid on a level floor, prepared for the purpose, and banked round to prevent the escape of the malm in the process of malming.

The quantity of clay required per 1000 bricks is variable, more strong clay being required than when milder qualities are used, on account of its greater shrinkage.

It is generally calculated that an acre 1 ft. deep, or about 1600 cubic yards of clay, will make 1,000,000 bricks, but strong clay will require from 1820 to 2000 cubic yards. For practical purposes the quantity may be thus approximately stated—

Strong clay—2 cubic yards per 1000 bricks
Mild clay—1¾ cubic yard per 1000 bricks.

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* A "spit" is the depth of a cut made by a spade in digging clay; it varies, according to the spade used, from 7 to 11 inches.

*Malming.*—It has been before explained that only the best London stock bricks are made entirely of malm, though the process of malming is resorted to for other descriptions of bricks where the quality of the clay renders it unfit for brickmaking without this addition. It will, therefore, be readily understood that the quantity of malm mixed with the clay in the ordinary process of brickmaking varies very considerably, so that it is impossible to predict what quantity of malm should be used; this must be left to the judgment of the brickmaker in each particular case, according to the quality of the earth.

The process of malming requires but little description. Water having been pumped into the mills, chalk is wheeled to the chalk-mill, and clay to the clay-mill, and when the mills are in motion the chalk is crushed and ground by the wheels, and runs through the outlet into the clay-mill, where both chalk and clay get well mixed by the harrows, and the liquid malm flows out of the clay-mill through the brass grating to the troughs, by which it is conducted to the heap of brick-earth. As the heap becomes covered, the troughs are shifted, so that the malm shall be equally distributed over every part of the heap.

When the whole of the brick-earth is passed through the wash-mill and so converted into slip, it is run into specially built earthwork tanks, termed "wash-backs," where it is left to settle for a month or more, until it has become sufficiently consolidated to bear a man walking over it. As the solid portion of the malm settles, the clear water is drained off from time to time, and may be returned to the wash-mills to be used over again. When the mass is sufficiently firm, the *soiling* is begun.

*Soiling.*—The proportion of ashes depends very much on the quality of the earth, but may be stated approximately at about 35 chaldrons for every 100,000 bricks. The soil is laid on the top of the malm or malmed earth, the thickness of the layer depending on that of the heap, about 3 in. of ashes being allowed for every spit * of earth.

The brick-earth is then allowed to remain undisturbed until the moulding season, which generally commences in April. The first process of the actual manufacture is—

*Tempering.*—The heap of solid material in the wash-back, prepared as above, is turned over by spade labour, and the ashes thoroughly incorporated with it, water being added if necessary to bring the mass to a proper consistency. The tempered clay is then wheeled on a barrow to the pug-mill, which, as before stated, is placed close to the clay heap, and immediately behind the moulding-stool.

*Pugging.*—The tempered clay being thrown in at the top of the mill (Fig. 12) gradually passes through it, and in so doing becomes so thoroughly kneaded as to be of an uniform colour, the ashes being equally distributed through the mass. In a horse-driven mill the quantity of clay pugged is about 1¼ cubic yards per hour, so that a horse working 10 hours per diem will grind 12½ cubic yards of clay, or sufficient to make 6250 bricks; but in a power-driven mill of good design, twice this quantity may be obtained.

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* See footnote on page 88.

As the clay issues from the pug-mill it is cut into block-like masses by a labourer, and placed ready for the moulder.

If the moulding process does not proceed as fast as the pugging, so that the clay will not be immediately used, the clay, as it comes out at the bottom of the mill, is removed with the cuckhold, and covered with wet sacks to prevent it becoming too dry for use, or it may be used at once.

*Moulding.*—Before commencing moulding, the moulding stool (Fig. 14) is provided with two heaps of dry sand, a tub of water, in which to place the strike, a stock board and brick-mould, and three sets of pallets. Everything being in readiness, and a supply of tempered clay having been placed on the stool by the feeder, whose business it is to carry the tempered clay from the pug-mill to the moulding stool, the *clot-moulder*, who is generally a woman, sprinkles the stool with dry sand, and taking a *clod*, or *clot*, from the heap of tempered clay, dexterously kneads and moulds it roughly into the shape of a brick, and passes it to the moulder on her left hand. The moulder, having sprinkled sand on the stock board, and dashed the mould (Fig. 15) into the sand heap on his left hand, places the mould on the stock board, and forcibly dashes the clot into it, pressing it with his fingers, so as to force the clay into the angles of the mould. He then, with the strike, which has been well wetted in the water-tub, removes the superfluous clay, which he throws back to the clot-moulder to be remoulded. The mould is then lifted off the stock board, and placed by the moulder against one of the pallets, which he catches dexterously with his fingers, and turning out the raw brick upon it, slides it along the page to the taking-off boy, and, lifting up the empty mould, dashes it into the sand, and replaces it on the stock board, preparatory to moulding a second brick. When he has moulded one set of bricks, he scrapes away the sand which has adhered to the mould during the operation, and then proceeds with another set. A moulder and clot-moulder, with the assistance of a feeder, a taking-off boy, and two men to wheel and hack the bricks, will make about 5000 bricks between 6 A.M. and 6 P.M.; but this quantity is often exceeded, some moulders being able to make 1000 bricks in an hour.

*Hacking.*—The raw brick is removed from the page by the taking-off boy and placed on the hack barrow (Figs. 16 and 17), and when the latter is loaded, dry sand is sprinkled over the bricks, and they are carefully wheeled away to the hack ground. The man then takes a spare pallet and places it on one of the bricks, which he carries between the two pallets to the ground, and sets it up carefully edgeways, taking care in removing the pallets not to injure the shape of the soft brick. One of the pallets is replaced on the barrow, and with the other another brick is removed; and the process is repeated till the twenty-six bricks have been placed on the ground, when the empty barrow is wheeled back to the moulding stool. In the meantime another barrow has been loaded, and is ready for wheeling to the hack ground. Three hack barrows are required, so that one of them is constantly being unloaded upon the hack ground, another loading at the moulding stool, and the third being wheeled to or from the hack ground. Thus, two men are necessarily employed in the operations of wheeling and hacking. The hacks are set up two bricks in width, the bricks being placed about ½ in. apart at right angles to the length of the hack.

After the bottom row of one hack is completed, a second hack is commenced, to give the bricks time to harden before a second course is laid on them. When the second course is commenced, the bricks must be placed fairly on each other, or they will be marked, which injures their appearance. The hacks are carried up in this way until they are 8 bricks high, when they are left for a few days to harden. To protect the bricks from frost, wet, or intense heat, straw, reeds, or loo-boards and hack-caps are provided, and laid alongside the hack, and with these the bricks are carefully covered up at night, and at such other times as the weather may render necessary. When half dry, they are *scintled* (literally, scattered), that is, set slantwise and farther apart, to allow the wind to pass freely between them. Each row slopes in the opposite direction to the one below it, so that each brick lies exactly across three others. Apart from protecting them from sun and rain, they receive no further attention until sufficiently dry for burning. The time required for drying varies from three to six weeks, according to the weather.

Hand-made bricks lose in drying about one-fourth of their weight, and in drying and burning about one-third. The average of machine bricks—those made of the stiff plastic clay—do not lose more than half the above amount from evaporation, and are, therefore, of much greater specific gravity than hand-made ones. The artificial drying of bricks over flues can, of course, only be carried on where coal is available and sufficiently cheap; it is then more economical than "hacking," as the number of spoiled bricks is much less when artificial drying is used.

*Clamping* * (Figs. 18 to 22).—A clamp consists of a number of walls or *necks*, 3 bricks thick, about 60 bricks long, and 24 to 30 bricks high, placed in an inclined position on each side of an *upright* or double battering wall in the centre of the clamp, the upright being of the same length and height as the necks, but diminishing from 6 bricks thick at bottom to 3 bricks thick at top. The sides and top of the clamp are cased with burned bricks.

The process of clamping requires great skill, and its practical details are little understood, except by the workmen engaged in this part of the manufacture. Scarcely any two clamps are built exactly alike, the differences in the methods employed arising from the greater skill or carelessness of the workmen, and local circumstances, such as the situation of the clamp, and the abundance or scarcity of burned bricks available with which to form the foundation and the outside casing.

The most nauseating fumes often arise from the stacks of bricks made and burned in this manner, which tend to make the immediate neighbourhood of one of these clamps anything but a desirable place for a residence, especially during the hot, close months of midsummer, which is the period during which the greater amount of this kind of brick burning is done. This is due to the use of ashes, frequently mixed with decomposed animal and vegetable matter, in the process of burning: pieces of bone, and other nitrogenous substances of a similarly objectionable character, not being infrequent. The following description may be regarded as typical of the best methods of construction, the details being varied in different localities. The reader should remember that, in it, the term *close bolting* signifies stacking bricks so that they shall be perfectly close to each other; and that *scintling* means stacking bricks with spaces between them.

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* This manner of burning bricks should not be confounded with the process called "clamping" in some parts of Great Britain, remote from London, which consists in burning bricks in a temporary kiln, the walls of which are generally built of "green" or unburned bricks.

*Foundation.*—The ground is first carefully drained and levelled, and made perfectly firm and hard. The exact position of the clamp having been fixed, the ground is formed with a flat invert, whose chord is equal to the width of the intended clamp The object of this is to give a *lift* to each side of the clamp, to prevent the bricks from falling outwards as the breeze becomes consumed. The ground being prepared, barrow-roads or "tramways" of sheet iron are laid down between the hacks, and extended to the clamp ground, to give an easy motion to the barrows.

*Upright.*—The upright is the first portion to be built. It is commenced by building about 45 ft. apart, two 9 in. battering walls of burned bricks laid on edge, which are termed close bolts, the length of each wall being equal to the thickness of the upright, which at the bottom is 6 bricks thick, or about 4 ft. 6 in.

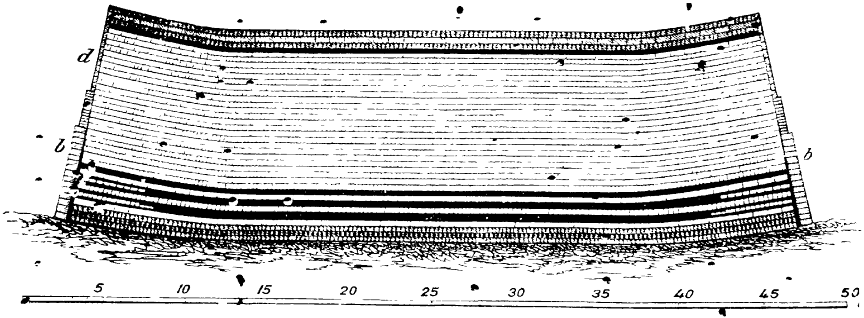

FIG. 18.—Transverse section of clamp (parallel to necks).

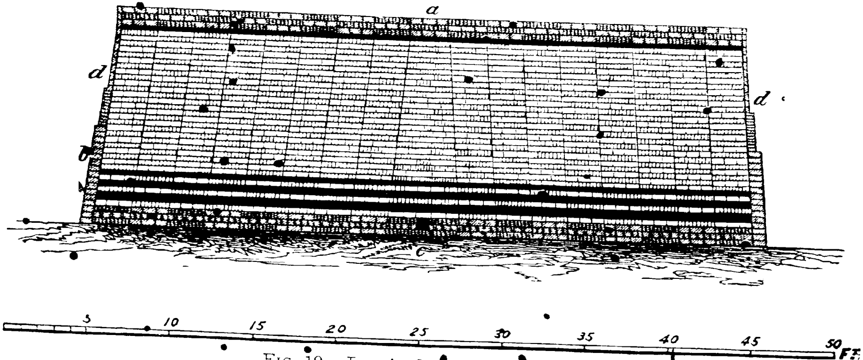

FIG. 19 —Longitudinal section of clamp.

*a*. The upright. *b.b*. Close bolts. *c*. Live hole. *d*. Bestowing.

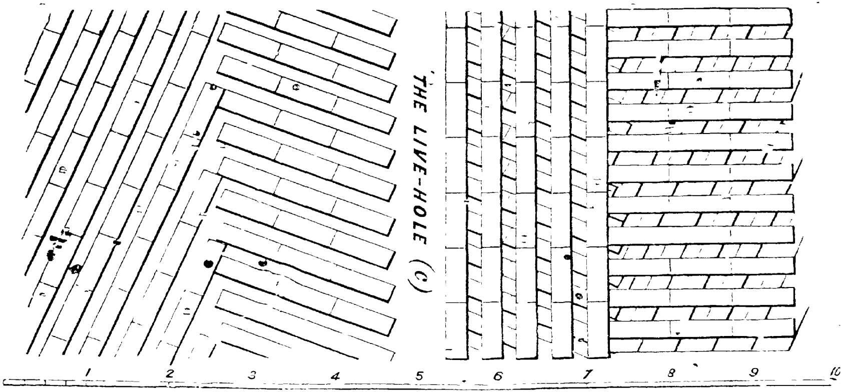

FIG. 20.—Plan of the lower course of scintles in clamp. FIG. 21.—Plan of the upper course of scintles in clamp.

It should be understood that the direction of the scintles, as well as that of the paving below it, are changed for every neck, so as to correspond with the upper work, as shown in the figures.

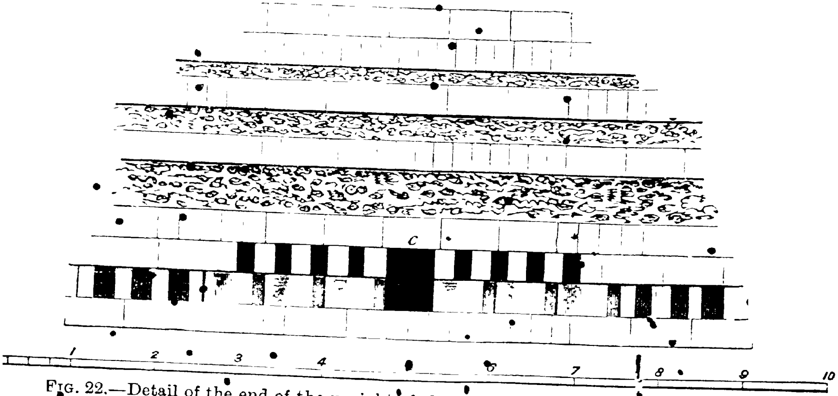

FIG. 22.—Detail of the end of the upright of clamp, showing the paving, the scintling, the live hole, (c) and the 7 in., 4 in., and 2 in. courses of breeze.

(their height is 16 courses, or about 6 ft.). Between these bolts a line is stretched, by which the upright is built true. The ground between the bolts is paved with burned bricks laid on edge, to exclude the moisture of the ground. Upon this paving are laid two courses of burned bricks with spaces between them, termed *scintles*. In the bottom course of scintles the bricks are laid diagonally about 2 in. apart. The second course consists of burned bricks on edge, laid across the lower one, in lines parallel to the ends of the clamp, and also 2 in. apart. In laying these two courses of scintles, a live hole is left about 7 in. wide, the whole length of the upright; and, on the completion of the second course, the live hole is filled up with faggots, and the whole surface covered over with breeze, which is swept or scraped into the spaces left between the bricks. On this surface is placed the first course of raw bricks, laid on edge and quite close, beginning over the live hole. Over this first course of raw bricks is laid a stratum of breeze 7 in. thick, the depth being increased, at the ends of the uprights to 9 or 10 inches, by inserting three or four bricks on edge among the breeze. The object of this is to give an extra lift to the ends. The first course of bricks, it should be observed, is laid *all headers*. Over the first layer of breeze is laid a second course of raw bricks on edge, *all stretchers*. This is covered with 4 in. of breeze, and at each end are inserted two or three bricks to increase the lift still more; but this time they are laid flat, not edgeways. Upon the 4 in. layer of breeze is laid a header course of raw bricks laid close, and on this 2 in. of breeze, without any extra lift at the end. To this succeed stretcher and header courses of raw bricks on edge, laid close up to the top of the clamp, a layer of breeze, not more than $\frac{3}{8}$ in. thick, being placed on the top of each course, except on the top course, which has 3 in. of breeze. The top of the upright is finished by a close bolt of burnt bricks. The upright is built with an equal batter on each side, its width diminishing from six bricks lengthways at the base to three bricks lengthways at the top. In order that the upright should be perfectly firm, it is necessary that the bricks should be well tied in at the angles; and, in order to obtain the proper width, the bricks are placed in a variety of positions, so that no very regular bond is preserved, as it is of more consequence to keep the batter uniform.

The close bolts first commenced, which form the outer casing of the clamp, are not built close to the raw bricks, there being a small space left between the clamp and the close bolting, which is filled up with breeze. The close bolts, however, are built with a greater batter than the ends of the upright, so that they just touch the latter at the 16th course, above which the clamp is built without any external casing. When, however, the upright is *topped*, and whilst the top close bolting is going on, the casing is continued up to the top of the clamp. This upper casing is called the *bestowing*, and consists of five or six courses of burned brick laid flat, forming a casing $4\frac{1}{2}$ in. or half a brick thick; and above the 6th course the bricks are laid on edge, forming a still thinner casing only 3 in. thick. When the weather is bad, and during the latter part of the brickmaking season, a little extra bestowing is given beyond what is here described. The great art in clamping consists in the proper construction of the upright, as the stability of the clamp depends entirely upon it.

*Necks.*—The remainder of the clamp consists of a number of necks or walls leaning against the upright. They are built in precisely the same way as the upright, as regards invert, close bolts, paving, scintling, breeze, and end lifts. But there is this essential difference, viz. that they are *parallel* walls, built in alternate courses of headers and stretchers laid on edge, each heading course in one neck being opposite to a stretching course in the next neck, and *vice versâ.* The thickness of each neck is made up of three bricks lengthways in the heading courses, and ten bricks edgeways in the stretching courses. The necks are close bolted at top, and bestowed in the same manner as the upright. When the last necks have been built, the ends of the clamp are close bolted, and bestowed in the same way as the sides. This operation completes the clamp.

The number of necks on each side of the upright may be extended to eight or nine, without an additional live hole; but if this limit be exceeded additional live holes are required. According to the judgment of the brickmaker or the demand for bricks, the live holes are placed seven, eight, or nine necks apart. It is not necessary that the additional live holes should pass under the centres of the necks, and it is more convenient to form each live hole so that the face of the last-built neck shall form one of its sides.

*Firing.*—To light the clamp, *live holes* or flues, 7 in. wide and 9 in. high, are left in the centre of the upright, and at every 7th, 8th, or 9th neck. These live holes extend through the whole thickness of the clamp, and are filled with faggots. In the close bolting surrounding the clamp, two bricks are left out opposite the end of each live hole, and to each of these openings a fire is applied made of coals and wood heaped up in a brick fireplace built round the opening, and known by the name of a *devil-stove.*

The fire soon ignites the faggots and adjacent "breeze." It is kept up for about a day, until the faggots in the live hole are thoroughly ignited, and as soon as this is found to be the case, the firing is stopped, and the mouth of the live hole closed up with bricks and plastered over with clay.

The clamp then continues to burn without attention until the whole of the breeze is consumed, which takes from three to six weeks.

The time of burning varies considerably. If the flues are placed nearer together, the burning may be completed in a fortnight or three weeks; but, if time is no object, the flues are further apart, and the clamp is allowed to burn off more slowly and regularly—producing better bricks.

In firing a large clamp with many live holes, it should be begun at one end only, the live holes being fired in succession, one after the other.

The bricks at the outside of the clamp are underburned; they are called *burrovers*, and are laid aside for reburning in the next clamp that may be built. The bricks near the live holes are generally partially melted and run together in masses called *clinkers* or *burrs.* The bricks which are not fully burned are called *place bricks,* and are sold at a low price, being unfit for outside work, or situations where they will be subjected to much pressure. The clinkers are sold by the cartload, for rockwork in gardens, concrete and similar purposes.

Great care is required to avoid the production of a large number of imperfectly burned bricks. If the clamp is badly constructed the bricks will not be sufficiently heated and instead of being sound and slightly vitrified they will be excessively porous, weak and "shaky."

*Another system of clamping* is to begin at one end and to follow with the necks in one direction only. This is done when the clamp ground is partly occupied by the hacks, so as to render it impossible to commence at the centre. When this system is adopted, the clamping begins with the erection of an end-wall, termed the *upright and outside,* which is made to batter very considerably on the outside, but of which the inside face is vertical. As regards dimensions and modes of building, the outside and upright is built in the same way as the ordinary upright, but it has, of course, no live hole under it, the first live hole being provided in the *centre* of the 2nd or 3rd neck. In this style of clamping the necks are all upright. The live holes are placed at every 8th or 9th neck, as in the usual system.

*Paving.*—The practice with regard to paving with burned bricks is very variable. Some clampers omit it altogether; others pave only where clamping for the first time on a new clamp ground.

*Scintles.*—When burned bricks are scarce, as in building the first clamp on a new ground, the second course may be laid with raw bricks. This is, however, a very objectionable practice.

*Live Holes.*—The live holes are sometimes close bolted at the sides, to prevent the breeze from the scintles falling into them. This is not often done, and its utility is questionable.

*Breeze.*—Some clampers put the 7 in. stratum of breeze on the top of the scintles, instead of placing it over the 1st course of raw bricks; very frequently the breeze is dispensed with after the 2 in. stratum, with the exception of the top layer. All clampers agree, however, as to the necessity of having the 7 in., 4 in., and 2 in. layers.

The several descriptions of hand-made bricks made for the London market are known by the following terms:—

*Cutters.*—These are the softest, and are used for gauged archers and other rubbed work.

*Malms.*—These are the best building bricks, and are only used in the best descriptions of brickwork; their colour is yellow.

*Seconds.*—These are sorted from the best qualities, and are much used for the fronts of buildings of a superior class.

*Paviours.*—These are excellent building bricks, being sound, hard, well shaped, and of good colour. They must not be confounded with paving bricks, having nothing in common with them but their name.

*Rough Paviours.*—These are the roughest pickings from the paviours.

*Pickings.*—These are good bricks, but soft, and inferior to the best paviours.

*Washed Stocks.*—These are the bricks commonly used for ordinary brickwork, and are a poor kind of malm brick.

*Grey Stocks.*—These are good bricks, but of irregular colour, and are not suited for face work.

*Rough Stocks.*—These are, as their name implies, very rough as regards shape and colour, and not suited for good work, although hard and sound.

*Grizzles.*—These are somewhat tender, and only fit for inside work.

*Place Bricks.*—These are only fit for common purposes, and should not be used for permanent erections.

*Shuffs.*—These are unsound and full of shakes.

*Burrs or Clinkers.*—These are only used for making artificial rockwork for cascades or gardens, concrete, etc.

*Bats.*—These are broken bricks, and are refuse.

*Pressed Bricks.*—These are made by using a portable press when the bricks are partly dry; usually before scintling them (p. 93).

*Front or Facing Bricks.*—These are made in the same way as stocks, but are fired in kilns, usually of the downdraught type, in order that they may become coloured in an attractive manner. Consequently, no breeze is mixed with the clay nor is solid fuel allowed to come into contact with the bricks. The colours so produced—mottled, plum, purple, and plain red—are entirely due to the burning and not to added chemicals, though sifted breeze is sometimes added to the clay for the darker tints. Such bricks are in great demand.

## 4. COST OR MANUFACTURE.

*Clay.*—The cost of brick-earth must depend very much on the circumstances of the locality, but it is usually considered to be worth 6*d.* to 2*s.* per 1000 bricks, exclusive of getting.

*Chalk.*—The cost of chalk is trifling where the works have the advantage of water carriage, as it can be brought to the canal wharfs round London at 3*s.* per ton. To this must be added the cartage, which, in some cases, is a serious expense.

*Sand.*—The above remarks also apply to the moulding sand, which is brought from the bed of the Thames, near Woolwich, in barges to the canal wharfs at 3*s.* per ton, a ton being about 1¼ cubic yard. To this must be added cartage, and labour in drying the sand to make it fit for use.

It is difficult to say what quantity of sand is used per 1000 bricks, as it varies with the clay, but the cost may be taken approximately at from 6*d.* to 10*d.* per 1000 bricks.

*Breeze.*—The quantity of breeze required varies according to circumstances; the proportion may be taken to range from 12 to 20 chaldrons per 100,000 bricks. The cost may be taken at about 5*s.* 6*d.* per chaldron.

*Soiling.*—The cost of soiling cannot be very accurately ascertained. The quantity of "soil" required depends much on the quality of the brick-earth; 35 chaldrons per 100,000 bricks may be considered a fair average. The cost per chaldron may be taken at 3*s.* 6*d.* to 5*s.* To this must be added the cost of barrowing to the clay heap, 14*s.* to 15*s.* per 100,000 bricks.

*Coals and Wood.*—The quantity of faggots required will depend on the number of live holes.

This item of expense is very trifling, say 3*s.* 6*d.* per 100,000 for faggots and coals to light the clamp.

*Water.*—The water required for the washing-mills is pumped into the troughs as before described, and as shown in Figs. 6 and 7.

That used in tempering the clay is pumped or brought in buckets from the nearest pond on the works. It is impossible to make any calculation as to the proportionate cost of the necessary supply of water to a brickfield, as it forms a portion of the cost of tempering, and cannot be separated from it.

*Machinery and Tools.*—The average cost of the machinery and tools required in a "London" brickfield of the simplest type is about as follows:—

| | | £ | *s.* | *d.* |
|---|---|---|---|---|
| Chalk and clay mills, together . . . . | £60 to | 70 | 0 | 0 |
| Pug-mill . . . . . . . . . | | 32 | 0 | 0 |
| Cuckhold . . . . . . . . . . | | 0 | 5 | 0 |
| For each moulder are required— . . . | | | | |
| 1 moulding-stool, complete, at . . . | | 2 | 0 | 0 |
| 1 mould " . . . | | 0 | 10 | 6 |
| 3 sets of pallets, 26 in each set . . | at 10*s.* | 1 | 10 | 0 |
| 3 bearing-off barrows . . . . . . | at 20*s.* | 3 | 0 | 0 |

In addition to the above are required a few planks, shovels, barrows, buckets, sieves, and other articles, the aggregate cost of which it is difficult to estimate.

A barrow of entirely different construction to that employed in "hacking" is used to convey the bricks to the clamp. On it the bricks are set quite close to each other several courses high. These are known as "crowding" barrows. They are driven at such a speed that the wheelers must run with them and not simply walk.

No buildings are required for the actual manufacture, though a drying and storage shed are convenient. Stabling may be required.

If labour-saving appliances are used, and engine power is employed instead of horses, the cost of installation will be much greater. Under such conditions and making a reasonable allowance for hack-caps and loo-boards, which are now generally used instead of straw, for protecting the bricks from the weather, the following figures will be found reasonably accurate :—

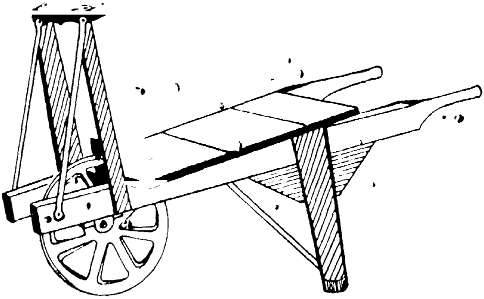

FIG. 23.—Crowding barrow.

| | For 500,000 bricks per season. | For 1,000,000 bricks per season. |
|---|---|---|
| Clay wash-mill and chalk-mill . . . . | £70 | £80 |
| Pug-mill and accessories . . . . . . . | 40 | 60 |
| Engine . . . . . . . . . . . . . | 60 | 80 |
| Shed and moulding-stools . . . . . . | 10 | 15 |
| Moulds . . . . . . . . . . . | 4 | 6 |
| Portable press . . . . . . . . . . . | 15 | 15 |
| Tram-rails, wagons and haulage . . . | 90 | 120 |
| Sheds, offices and stables . . . . . | 150 | 220 |
| Washbacks . . . . . . . . . . . | 25 | 40 |
| Hack-caps and loo-boards . . . . . . | 120 | 250 |
| Barrows, pallets, spades, etc. . . . . | 26 | 40 |
| | £610 | £926 |

Many brickmakers estimate £1 per 1000 bricks annual output, but this is too low for a small yard at the present day.

The present cost of production for bricks made as described in this chapter, near London, may be taken as follows:—

| | Per 1000 bricks. £ | s. | d |
|---|---|---|---|
| Rent and royalty | 0 | 2 | 0 |
| Ashes and fuel | 0 | 3 | 6 |
| Removing top mould | 0 | 0 | 2 |
| Digging earth | 0 | 0 | 7 |
| Soiling and turning earth | 0 | 0 | 6 |
| Chalk and expense of washing | 0 | 1 | 4 |
| Pugging | 0 | 0 | 6 |
| Moulding | 0 | 5 | 0 |
| Sand | 0 | 0 | 6 |
| Cover boards | 0 | 0 | 2 |
| Hacking and clamping | 0 | 2 | 0 |
| Bolting, sorting, etc. | 0 | 0 | 3 |
| Loading | 0 | 0 | 6 |
| Implements, etc. | 0 | 0 | 6 |
| Superintendence | 0 | 0 | 6 |
| Interest on capital | 0 | 1 | 0 |
| Bad debts and repairs | 0 | 1 | 6 |
| Preparing hacks, obtaining water, making roads, building, office expenses, etc. | 0 | 2 | 0 |
| | 1 | 2 | 6 |

Prices vary so greatly in different localities, however, that no "average" figures can be perfectly accurate.

## CHAPTER IV.

### HAND BRICKMAKING IN SUFFOLK AND LINCOLNSHIRE.

Two kinds of bricks are made in Suffolk, viz. reds and whites. The latter are much esteemed for their shape and colour, and large quantities are annually sent to London for facing buildings.

White bricks are made in many parts of England, but the Suffolk whites have the pre-eminence over all others.

Some of the white bricks made near Lincoln are notorious for *swelling* when laid in work, which causes them to throw off the mortar joints, and renders it impossible to make use of them in good work. The clay from which these bricks are made extends from the Witham northwards as far as the Humber, and apparently possesses the same property throughout this distance, the bricks made from it at various points between the Witham and the Humber having the common defect of swelling after burning.

The Humber silt has been successfully used for making large numbers of bricks for the Grimsby Docks and town. These bricks are remarkable for their colour, which varies in the same brick from dark purple to dirty white, passing through various shades of blue, red, and yellow, in the space of two or three inches. The silt, when first dug out of the bed of the Humber, is of a dark blue colour, which soon, from exposure to the air, changes to a brown.

The bricks made for the Dock Company were burned in close clamps—fired with layers of small coal, but without coal-dust or ashes being mixed with the clay as in London brickmaking. With the first clamps there was much waste, the quantity of fuel being excessive, and the bricks were cracked and made brittle in consequence; but the experience obtained by the first trials has led to the production of a sound well-burned brick, with, however, the peculiar colour above mentioned.

Kilns as well as clamps are used in this part of Lincolnshire, their construction being similar to that of the kilns in general use in the Midland Counties.

Machine-made bricks are also produced.

In Suffolk only two qualities of red bricks are distinguished, viz. outside and inside; four qualities of white bricks are recognised, viz. best, 2nd, 3rd, and murrays.

*Clay.*—The supplies of brick-earth are chiefly derived from the plastic clays lying above the Chalk, although blue clay is occasionally used.

The clays in most parts are too strong to be used alone, and have, consequently, to be mixed with a white loam, a milder earth, or with chalk.

*Tempering.*—The clay is turned over in February and March, and in some parts of Suffolk it is passed through a wash-mill, but this is not generally the case.

Tempering is sometimes performed by spade labour, but a pug-mill is now generally used.

*Moulding.*—The brick mould is of wood, shod with iron; the dimensions vary slightly according to the nature of the clay, but are usually as follows:

$9\frac{7}{8}$ in. long by $4\frac{15}{16}$ in. wide and $3\frac{1}{4}$ in. deep. There is no hollow formed in the bottom of the brick for the mortar joint. Brass moulds are seldom used.

*Sea sand* is commonly used in the process of moulding, for sanding the mould and the table.

A "strike" (p. 84) is used for taking off the superfluous clay from the mould.

*Drying.*—The bricks are not dried on flats as in the Midland Counties, but are taken directly from the moulding-stool to the hacks. Sheds are used in some yards, and drying-houses with flued floors are used in winter for pantiles and kiln tiles, but not for bricks.

The length of a hack is about 70 yards, and each moulder will keep four hacks going.

The *time* required for drying in the hacks varies according to the weather, but may be said to average about eighteen days for red bricks. White bricks dry rather more quickly.

The *contraction* of the clay in drying amounts to about $\frac{7}{8}$ in. in the length of a brick, and, if properly burned, the shrinkage in the kiln is imperceptible.

*Burning.*—The construction of the kiln is quite different from that of the kilns used in other parts of England, having two arched furnaces running its whole length underneath the floor, which is formed of a kind of latticework, through the openings of which the heat ascends from the furnaces below. The bricks are commonly set in the kiln in bolts two bricks long by ten on; but some brickmakers prefer to cross them in the alternate courses, in order to admit the heat more freely. The *fuel* used is coal, and the quantity consumed is about half a ton per 1000 for white, and 7 cwt. per 1000 for red bricks. The *time of burning* is about 60 hours for white, and 40 hours for red bricks; white bricks requiring a greater heat than the red ones to bring them to their proper colour.

During recent years this type of kiln has largely been replaced by downdraught and continuous kilns.

*Cost of Manufacture.*—This, in a well-managed yard, is approximately—

| | Per 1000 bricks. £ | s. | d. |
|---|---|---|---|
| Clay digging | 0 | 2 | 0 |
| Tempering | 0 | 1 | 0 |
| Moulding | 0 | 4 | 6 |
| Drying | 0 | 0 | 6 |
| Moulding sand | 0 | 0 | 9 |
| Barrowing from hacks and setting kiln | 0 | 1 | 9 |
| Burning | 0 | 2 | 6 |
| Drawing kiln | 0 | 0 | 6 |
| Stacking | 0 | 0 | 6 |
| Coal, about | 0 | 7 | 0 |
| Rent, royalty, tools, and repairs | 0 | 3 | 6 |
| | £1 | 4 | 6 |

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## CHAPTER V.

### HAND BRICKMAKING IN NOTTINGHAMSHIRE AND NEIGHBOURING COUNTIES.

THE mode of making bricks in Nottinghamshire and the neighbouring counties, including Derby, Leicester, and parts of Lincoln and Staffordshire, presents several peculiarities, of which the principal are—

1st. The use of rollers for crushing the brick-earth.

2nd. The use of "copper" moulds.

3rd. The hacking of the bricks under cover.

The use of "copper" moulds has been for some years gradually extending to other districts, and will probably, sooner or later, become general for the manufacture of superior qualities of hand-made bricks.

The old houses in Nottingham are built with very thin bricks, much of the old brickwork gauging 10½ in. to 4 courses in height, including mortar joints. These bricks are of a dark red colour, and were made in works that have been long since abandoned. The bricks now made are much thicker, the walls of many new buildings gauging 21 in. to 7 courses in height, or about 13⅛ in. to 4 courses in height, including mortar joints. The common bricks are of a very uneven colour, which arises partly from the manner in which they are set in the kiln, and partly from the want of care in selecting the clay and the quantity of limestone ground up with it. From this circumstance the fronts of many of the new buildings have a mottled appearance, which is extremely unsightly.

In many brickworks the earth used is not plastic clay, but a very hard marl, which cannot be brought into a state of plasticity by the ordinary processes of weathering and tempering without bestowing upon it more time and labour than would be repaid by the value of the manufactured article. It is, therefore, ground, and reduced to any state of fineness required, according to the number of sets of rollers used and the gauge to which they are worked, all hard lumps and pieces of limestone,* which would otherwise have to be picked out by hand, being crushed to powder, so as to be comparatively harmless.

The advantages and disadvantages of the use of rollers may be thus briefly stated—

1st. Much valuable material is used which would not be available for brickmaking by the processes described in previous chapters.

2nd. The process of grinding, if properly conducted, greatly assists the operations of the temperer by bringing the earth into a fine state, quite free from hard lumps.

3rd. On the other hand, the facilities afforded by the use of rollers for working up *everything* that is not too hard to be crushed by them, make many brickmakers fail to pay proper regard to the nature of the material. A common practice is to work the rollers to a wide gauge, so that comparatively large pieces of limestone pass through without being crushed. Where this is the case, it need hardly be said that the bricks are worthless. They may appear sound, and may have a tolerable face, but rain and frost soon destroy them, and, in situations where they are exposed to the weather, they will become completely perished in a few years.

The following description of the mode of making bricks at Nottingham applies with sufficient accuracy to the practice of the brick-yards for many miles round. It will, of course, be understood that in no two yards is the manufacture carried on in exactly the same way; there being differences in the designs of the kilns, the arrangement of the buildings, and other points of detail, which may be regulated by local circumstances, or which, from the absence of any guiding principle, may be left to chance; the general features, however, are the same in all cases.

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* To prevent damage to the rollers, all pebbles and hard stones must be picked out by hand before grinding. Where the brick-earth used is much mixed with gravel, the only resource is the use of the wash-mill.

*Brick-earth.*—The brickmakers of Nottingham and its immediate vicinity derive their supplies of brick-earth from the strata of red marl* overlying the red sandstone on which the town is built, which in its turn rests on the Coal Measures. The marl abounds with loose and thin layers of *skerry*, or impure limestone, and in many places contains veins of gypsum, or, as it is called, *plaster stone*, which are extensively worked near Newark, and other places, for the manufacture of plaster of Paris.

The water from the wells dug in these strata is strongly impregnated with lime compounds.

The colour of the bricks made at Nottingham and in the neighbourhood is very varied. For making red facing bricks the clay is selected with great care, and only certain beds are used. For common bricks, the earth is taken as it comes, and the colour is very irregular and unsatisfactory, varying from a dull red to a dirty straw colour. Some of the marls burn of a creamy white tint, and have been lately used with much success in making ornamental copings and other white ware.

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* The term *marl* used here has reference to an earth of a friable nature which does not adhere to the spade when dug, and cannot be cut like a plastic clay. It must not be confused with the marls of the London district, which contain finely divided chalk.

Stones and pebbles are picked out by hand, but the pieces of limestone are generally left to be crushed by the rollers, and much bad material is worked up in this way which could not be used if the tempering were effected by treading and spade labour only.

There are, however, many beds which are sufficiently free from limestone not to require grinding, and when these are worked the rollers are not used.

For making rubbers for gauged arches, the clay is carefully picked, and run through a wash-mill into pits, where it remains until by evaporation and settlement it has attained a proper degree of consistency. The clay for this purpose is generally mixed with a certain quantity of sand to diminish the labour of rubbing the bricks to gauge, the proportion varying according to the quality of the clay. The sand used for this purpose is the common local rock sand, which burns to a red colour.

*General Arrangement of the Works.*—The hilly, nature of the ground offers great facilities for draining the workings and for bringing the ground into cultivation again after the clay has been exhausted; so that it is not unusual to erect a works near to a main road, and to sell the land between the two for building purposes.

The proprietor of a brickworks usually rents the required land from the owner of the soil, at an agreed price per acre, and in addition to the rent pays for all clay dug, whatever its quality, at a set price per thousand bricks made and sold, exclusive of those used for the erection and repairs of the buildings on the works.

The arrangement of the several buildings varies with each yard; but the principle on which they are laid out is the same in all cases, viz. to advance towards the kiln at each process, so as to avoid all unnecessary labour. This will be understood by inspection of Fig. 24, which, it must be understood, is not an exact representation of a particular brick-

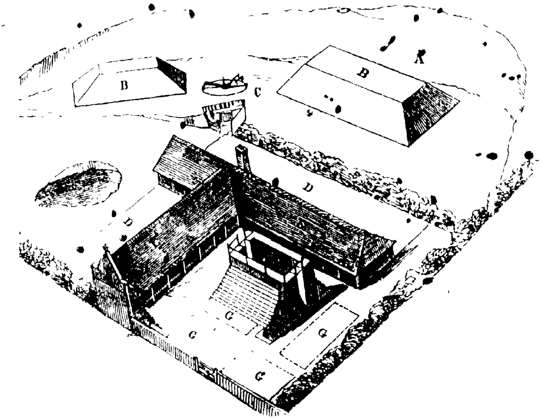

FIG. 24.—General view of a brickworks.

A. The face of the workings.
B.B. Heaps of brick-earth, dug in the autumn, to be worked up the following season, after being mellowed by the winter frosts.
C. The clay-mill or crushing rolls.
D.D. The working floors, generally 10 yards wide.
E. The hovel or drying shed.
F. The kiln.
G. Spaces for bricks stacked ready for sale.

works, but a diagram to explain the principle of arrangement usually followed. The pits (A), from which the clay is dug, are at the rear of the works, and at some little distance from them is placed the

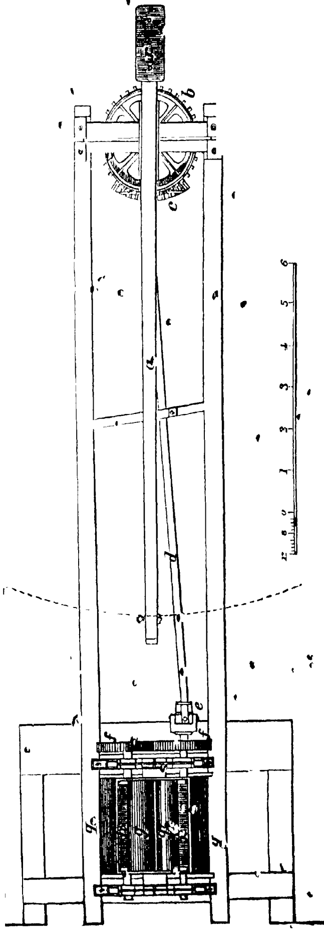

FIG. 25.—Plan of horse-driven clay-crushing rolls.

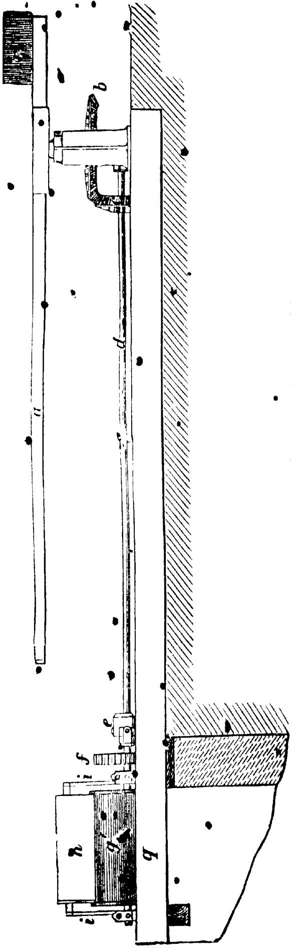

FIG. 26.—Elevation of horse-driven clay-crushing rolls.

clay-mill (C), which, to save labour in wheeling the clay, may be shifted from time to time as the workings recede from the kiln by the exhaustion of the clay. This is, however, not always done, as, where the mill has been fixed in a substantial manner, the saving in labour would not repay the cost of re-erection.

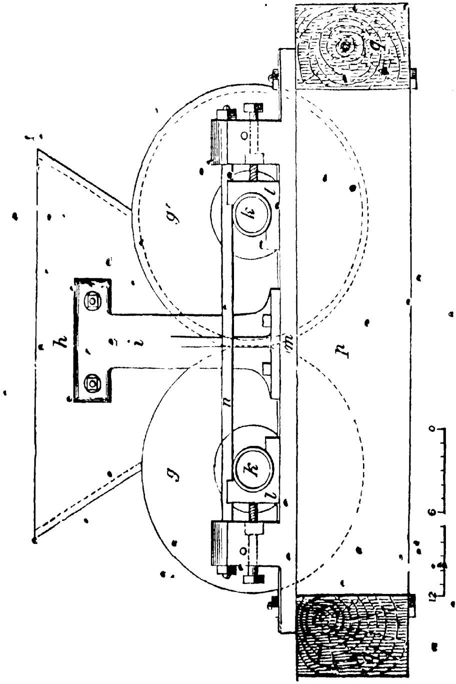

FIG. 27.—Cross-section of crushing rolls.

*Clay-mill.*—The machinery used in grinding the clay is very simple. It consists of one or more pairs of cast-iron rollers (Fig. 27), set very close together in a horizontal position, and driven by a horse who walks in a circular track, and, by means of the beam to which he is attached, puts in motion a horizontal bevelled driving-wheel placed at the centre of the horse track. An engine is more satisfactory than a horse for driving these rollers, being both more regular and more powerful.

Figs. 25 to 27 represent a one-horse mill with a single pair of rollers 18 in. in diameter, and 30 in. long.

In these illustrations the lettering has the following significance:—

*a.* Horse beam, 12 feet long, from centre of horse tract to centre of driving-wheel
*b.* Bevelled driving-wheel.
*c.* Pinion.
*d.* Driving-shaft, 1½ in. diameter.
*e.* Universal joint.
*f f.* Spur wheels.
*g g* Cast-iron rollers 18 in. diameter and 32 in. long. The roller marked *g'* is longer than the other, having a flange round each end by which the roller *g* is kept in its proper position. The roller marked *g'* is connected by the universal joint *e* with the driving-shaft *d*.
*h.* Wooden hopper.
*i i.* Cast-iron standards to support the hopper.
*k k.* Axles of rollers.
*l l.* Bearings for the axles *k k*. These bearings are made to slide on the bottom plate *m*, in order that the gauge of the rollers may be adjusted at pleasure.
*m.* Bottom plate, on which the bearings rest.
*n.* Strengthening bar.
*o o.* Adjusting screws, by which the rollers can be set to any gauge, according to the degree of fineness to which the clay is required to be ground.
*p.* End beam of framing.
*q q.* Sides of framing.
*r.* Balance weight to horse beam.

From these details it will be seen that a horizontal shaft, connected at one end with one of the rollers by an universal joint, and having a bevelled pinion at the other end, communicates the motion of the driving-wheel to the rollers by spur-wheels keyed on their axles. The clay is tipped in a wooden hopper placed over the rollers, and passing slowly between the latter falls on a floor about 8 feet below them, where it is tempered for the moulder.

This floor is inclosed on three sides with brick walls which support the wooden framework of the machinery. The clay is prevented from adhering to the surfaces of the rollers by strong knives fixed on their under-sides.

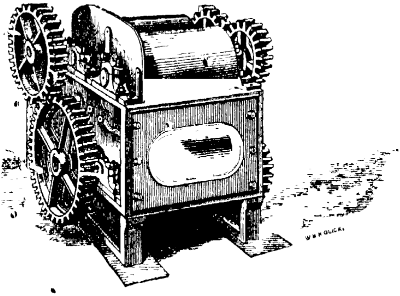

FIG. 28.—Double crushing rolls.

Many clay-mills have only one set of rollers, but the addition of a second set (Fig. 28) is a great improvement. In this case, the bottom rollers are placed almost in contact with each other, and should be faced in the lathe to make them perfectly true. If only one set be used this is a needless expense, as the gauge to which they are worked is too wide for any advantage to be derived from it.

When the rollers are not faced in the lathe, they are cast upright in loam moulds, which insures great accuracy in casting, and renders turning unnecessary, where only one set of rollers is employed. The arrangement of the rollers, when two or more sets are employed, is shown in Chap. VI., Figs. 43 to 45, which shows the construction of the clay-mills used in Staffordshire.

It cannot be too strongly insisted upon that the machinery should be boxed up close, so as to prevent stones or clay from clogging the wheels, as where this is not done the machinery will unavoidably become deranged in a very short time.

Fig. 29 is a diagram showing an improved arrangement of the ordinary clay-mill, in which the horse track is raised to the level of the top of the hopper, the whole of the machinery under the hopper being completely boxed up, so that no dirt or stones can lodge on the wheels. The driving-wheel is placed in a circular pit lined with brickwork to keep up the horse track to the required height.

In all but the more isolated districts more powerful rolls driven by engine-power are now used (see Chaps. VI. and VIII.)

The quantity of work performed will, of course, vary greatly, according to the distance between the rollers and the consequent fineness to which the clay is ground. One horse-mill will grind sufficient clay to keep six moulders fully employed.

The length of time during which a clay-mill will last in good working condition is chiefly regulated by the wear of the rollers. If the iron is of very uniform quality, and care be taken to pick out all

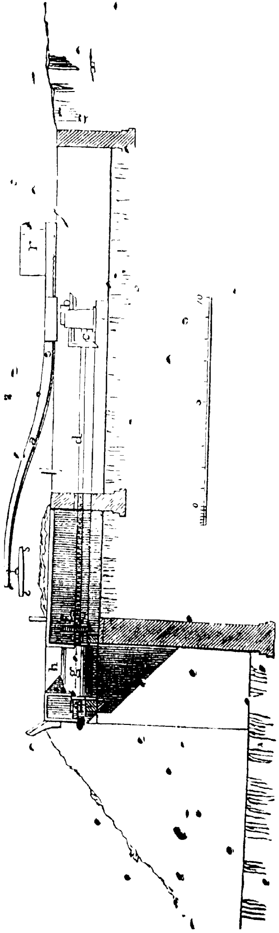

Fig. 29.—Improved arrangement of crushing rolls

the pebbles from the clay, a pair of rollers will last many years.

*Wash-mill.*—The wash-mill is only used in the manufacture of arch bricks, and does not differ from that employed in other places (p. 79).

*The Pug-mill* is comparatively new to Nottinghamshire brick-yards; the tempering of the clay, after grinding, being formerly effected by treading and spade labour. Instead of the clay being tempered directly after grinding, it was, at one time, deposited in damp cellars for a year or more to ripen. This is no longer the case.

*The Moulding Sand* used is the local rock sand, which burns to a red colour. In making white bricks this is a great disadvantage, as it causes red streaks. The sand is only used to sprinkle upon the table to prevent the clay from adhering thereto. Sand with a sharp grit is preferred.

*The Moulding Table* is shown in Fig. 30. It comprises a sloping plank (A), placed at one end of the table to enable the moulder's boy to deposit the clay on the table. At the same end (B) of the table, the tempered clay is deposited. A sand-box (C) is not always fixed. In many cases it is a detached box, on three legs, placed close to the moulding-table.

The part of the table on which the clot is moulded (D) is near the centre.

The clot is put into the mould at (E), immediately in front of the water-box (F), in which the moulder dips his hands each time he moulds a brick. A slip of wood (G) on which the plane rests in order to raise it from the table, that the moulder may take it up the more readily, is placed near the water-box (F).

The brick is taken off the table at (H). This part of the table is always very wet, and the slush runs

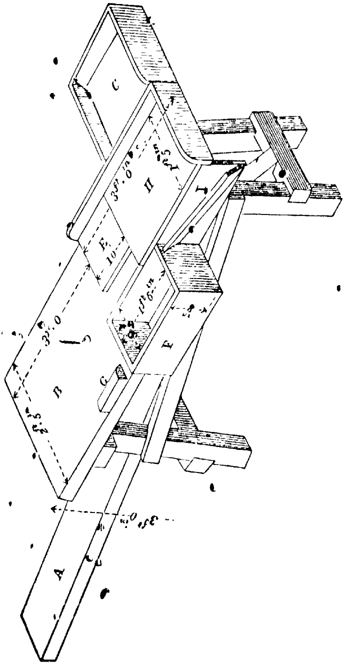

Fig. 30.—Moulding-table.

off into a gutter (I) to carry off the drippings from the table into a tub placed beneath it, but not shown in the drawing. If the water were allowed to run down on the working floor, the latter would soon become wet and slippery, and unfit for receiving the bricks.

In the operation of moulding, the moulder stands in front of the table, with the water-box immediately in front of him, the tempered clay at his right hand, and the sand-box at his left. The boy who takes off the newly made bricks, and brings back the empty mould, stands on the side of the table opposite the moulder, to the right of the water-box, in which he washes his hands after each journey, to prevent the clay from drying on them.

The cost of a moulding-table varies according to the care with which it is made. Such a one as shown in the illustration will cost about 30*s.*, and will last, with occasional repairs, for several years. The part where the bricks are moulded soon becomes worn, and has to be cased, as shown in the illustration. This casing extends over the part where the brick is taken off by the carrier boy; but, as the wear is not uniform over this space, the casing is in two or more pieces, the part where the brick is moulded wearing much faster than the others, and requiring renewal sooner.

*Brick Moulds.*—At one time the moulds were made of wood, but these have been almost entirely superseded by brass, or, as they are technically called, "copper" moulds.

The mould has no bottom as in the London practice, nor is it placed upon a raised moulding-board as in Staffordshire; but rests on the moulding-table itself, the top and bottom beds of the brick being formed at two distinct operations with a little instrument called a plane (p. 132).

There are several different ways in which these moulds are made. Sometimes the brass work is merely an inside lining, screwed to a wooden mould; but the best construction appears to be that shown in Fig. 31, in which the mould is of brass, cast in four pieces, and riveted together at the angles. the sides projecting half an inch beyond the ends. Each casting has a flange at top and bottom, forming a rim half an inch wide all round the top and bottom of the mould. The outside of the mould is cased with wood, secured to the brass by the rivets. To give a hold to the latter, each pair is passed through a piece of sheet copper, as shown. These moulds are costly, and formerly a pair of moulds cost £2, but they may now be had for £1 5s. the pair.

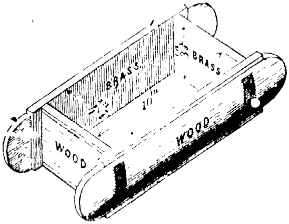

FIG. 31.—"Copper" brick mould.

It will be seen, by reference to the engraving, that the brass overlaps the woodwork all round the mould on each side, and these portions of the mould wear away very rapidly, so that the bricks made at the close of the season are considerably thinner than those made at its commencement. This renders it necessary to renew the projecting rims from time to time as they become worn down with use, and this will require to be done every season if the mould has been in constant use. It is an expensive operation, as the new rim has to be brazed on to the old part, and this must be done with great nicety, and so as to make a perfectly flush joint on the inside of the mould, or the latter would be rendered useless. The cost of *plating* a pair of moulds is nearly the same as their original cost, and therefore it would be preferable to use the moulds until they are quite worn out, and then to replace them with new ones. The expense of replating with brass has induced a trial of iron rims, but they have not been found to answer.

The moulds for making quarries are somewhat different, only two of the sides being cased with wood, whilst the others are stiffened by strengthening ribs cast on the sides of the mould.

The use of copper moulds is confined to the making of building bricks, and quarries for paving floors, their weight and great cost preventing their employment for larger articles.

*The Plane* (Fig. 32) is usually made 9 in. long by 3 in. broad, with a handle at one end. Its use is to compress the clay in the mould, and to work over the top and bottom beds of the brick to give them an even surface.

*The Strike* (p. 84) is not used.

*The Clapper* (Fig. 33) is simply a piece of board 12 in. by 6 in. with a handle on one side. It is used to flatten the surfaces of the bricks as they lie on the floors, and the bricks are also beaten with it during the process of hacking, to correct any warping which may have taken place in the first stage of drying.

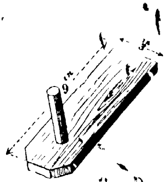

FIG. 32.—Plane.

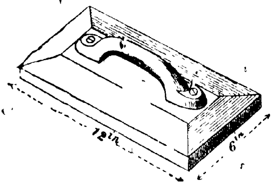

FIG. 33.—Clapper.

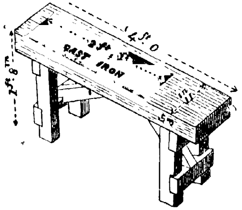

FIG. 34.—Dressing bench.

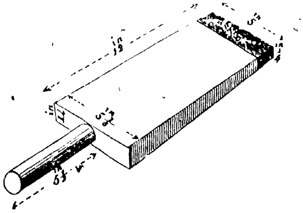

FIG. 35.—Dresser.

*Dressing Bench* (Fig. 34).—This is simply a stout bench, to which is fitted a plate of cast iron, on which the best front bricks are rubbed or *polished*, to make them perfectly true and even; the workman, at the same time, beating them with a wedge-shaped beater, tipped with iron, called a *dresser*, Fig. 35. This operation toughens the brick, corrects any warping which may have taken place, and leaves the arrises very sharp.

*The Flats*, or working floors, are prepared with care, by levelling and rolling, so as to make them hard and even, and are laid out with a slight fall, so that no water may lodge on them. They are well sanded, and constant care is requisite to keep them free from weeds. Their usual width is about 10 yards. In unfavourable weather a single moulder will sometimes have as many as 7000 bricks on the flats at once, for which an area of from 300 to 400 superficial yards will be required. This, however, is an extreme case, and in good drying weather a moulder does not require more than half that extent of floor.

*The Hovel*, or drying-shed (E, Fig. 24), in which the bricks are hacked, generally forms two sides of a rectangular yard adjoining the public road, the kiln being placed as close to the hovel as practicable, and the working floors or flats in the rear of the latter. By this concentration of plan, the distance to which the bricks have to be carried between the successive processes of moulding, drying, hacking, and burning is reduced to a minimum. This is important, if the raw bricks are shifted by hand and not by barrows.

It is generally built in the roughest and cheapest manner possible, with open sides and a tiled roof, supported by wooden posts or brick piers; the width of the hovel is about 18 ft., or rather more than the length of a hack, but the eaves are made to project a couple of feet or so beyond this distance, in order to give additional shelter from the rain, for which reason, as well as for the sake of economy, the eaves are carried down so low as to make it necessary to stoop to enter the shed.

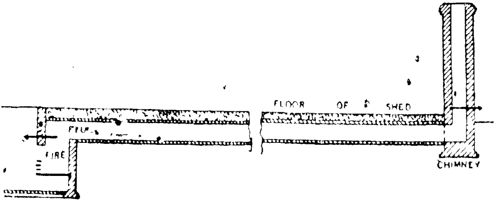

Fig. 36.—Drying floor with flues.

Some hovels have flues under the floor, the fire-places being placed in a pit sunk at one end of the hovel, and the chimney at the opposite end (Fig. 36). In some drying-houses the flues are made to return nearly to the furnaces before they are led into the chimney, so that the latter is close to the former. These flues are used when the demand for bricks is so great that sufficient time cannot be allowed for drying in the open air, and also during inclement seasons. The sides of the hovel are then walled up with loose brickwork to retain the heat. No specific rule can be given for the relative sizes of the hovel and the drying floor. The common practice appears to be to make them of the same length, which allows ample room, and enables the moulder to keep a portion of his shed always available as a drying-floor when the weather is too wet to allow of the bricks being laid out on the flats. When this is the case the moulder protects the raw bricks from draughts, by surrounding them with a skirting, so to speak, of planks. This is a very necessary precaution, for the currents of air from different parts of the shed would cause the bricks to dry unequally, and they would crack and become unsound. Matting is frequently hung up at the sides of the hovel for this purpose, and is also used in some yards to prevent the finer clays, when tempered, from drying too rapidly.

The above description applies to the ordinary hovel, but the best front bricks are dried wholly under cover in a brick hovel enclosed by walls on all sides, and furnished with flues, by which the place is kept at a regular temperature. The expense of conducting the whole of the drying under cover in this manner is too great to allow of its general adoption for common bricks made by hand.

*Machinery for pressing Bricks.*—In some yards presses are used for pressing front bricks, and with considerable success. It is, however, questionable whether pressed bricks are as durable as those dressed by hand, though the latter are becoming more and more scarce. In making machinery for this purpose the great desiderata are to make the metal mould in which the brick is compressed so strong that it shall not spring on the application of the power; and that the piston shall exactly fit the mould: when, from bad workmanship or long use, this is not the case, the clay is forced between the piston and the mould for a short distance, leaving a slightly raised edge all round the side of the brick.

Without entering upon a comparison of the respective merits of machine-pressed bricks and those dressed by hand, it may be pointed out that the operation of dressing on the bench requires an experienced workman, whilst a common labourer can use a machine. For this reason machine-pressed bricks can be produced much cheaper than those dressed by hand, and there is little inducement to employ the latter process.

*Kilns.*—The kilns used vary considerably both in design and constructive principles. Formerly "Scotch kilns" were usually employed for common bricks, and "downdraughts" for facing bricks, but in recent years continuous kilns (p. 49) have replaced intermittent ones on account of the greater saving in fuel. For common bricks, where the output is not sufficient to justify the erection of a continuous kiln, the Scotch or "Scove" kiln is still used.

The kiln shown in Figs. 37 to 42 is of this type, though rather weak at the angles.

It consists of four upright walls, enclosing a rectangular chamber. The floor is sunk about 4 ft. below the general surface of the ground, and is not paved. The doorways for setting and drawing the kiln are merely narrow openings at the ends of the kiln, raised a step above the ground, and about 5 ft. from the floor. The fire-holes are arched openings opposite each other on the sides of the kiln, lined with fire-bricks, which require to be renewed from time to time, generally every season. The width of these holes is reduced to the required space by temporary piers of brickwork, so as to leave a narrow opening about 8 in. wide and about 3 ft. high. This will be understood by reference to Fig. 40, in which the dark shading shows a fire-brick lining; and the unshaded parts the temporary piers. These last are pulled down whenever the fire-brick lining requires to be renewed.

In many kilns, however, the fire-holes are made at once of the requisite width, and finished at top by oversetting the bricks on each side till they meet, instead of being arched over.

On each side of the kiln a pit is sunk to the level of the floor,* and covered with a lean-to roof, which protects the fuel and the fireman from the weather, and prevents the wind from setting against the fires. The walls of the kiln are about 3 ft. thick, and are built of old bricks, rubble stone, and the refuse of the yard. No mortar is used, as the use of lime would destroy the brickwork, under the intense heat to which the walls are exposed. The bricks are therefore set in loam or fire-clay, if the latter can be readily procured; it usually can be bought from the neighbouring collieries.

Very great care is requisite in drying a newly built kiln, or the walls will be cracked at the first firing, and the thicker the walls the greater the care necessary.

Instead of being built with walls of parallel thickness, resting on arches, as in the example just described, some kilns are built with walls of great thickness at the bottom, and diminishing by set-offs until, near the top of the kiln, they are comparatively thin. Many kilns also are provided with massive buttresses at the angles, to counteract the tendency which the walls have to lift themselves with the heat.

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* In order to save expense, this type of kiln is frequently erected on the ground-level, but the fires are then more affected by wind than when the kiln is partially sunk.

So long as the brickwork is sufficiently thick to retain the heat, no purpose is attained by increasing the strength of the walls, unless they are made so massive that they are unaffected by the heat externally, and heavy enough to counteract the *lifting* caused by the expansion of the sides exposed to the fire. In the one case the walls expand bodily with the heat, forming large and dangerous cracks; in the other, separation takes place between the inside and outside of the walls, from the expansion of the parts most exposed to the heat, and the kiln soon requires relining.

The kiln shown in Figs. 37 to 42 is an example of the mode of building with the walls of the same thickness top and bottom; that shown in Fig. 42A is one of a more massive construction, and has buttresses at the angles. The upper part of this kiln is formed by building, in a temporary manner, a thin parapet round the inside of the top of the walls, about a couple of feet in height. This expedient is often resorted to for the sake of increasing the capacity of a kiln at a small expense.

In this kiln the doorways do not reach to the top of the walls, and are arched over, so that the latter form a continuous terrace all round the top of the kiln, on which a thin parapet is built up in a temporary manner, to increase its capacity.

Some kilns are provided with a flight of steps by which access is obtained to the top (Fig. 41); in others, ladders are used for this purpose. Many kilns have also a kind of light fence round top made of rough poles. This serves as a protection from falling, and as a scaffold to which screens may be hung in windy weather to keep the wind from setting on the top of the kiln.

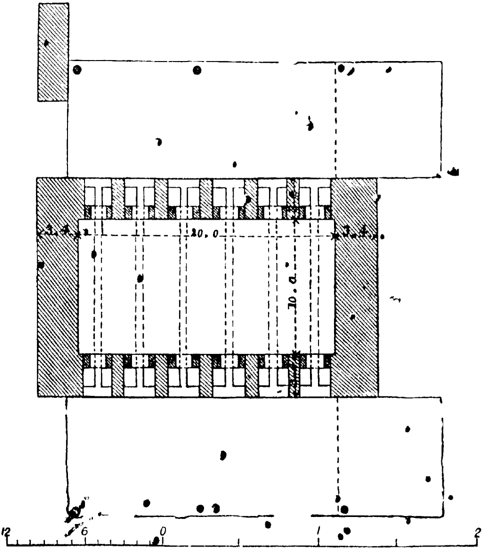

FIG. 37.—Plan of kiln at ground-level, showing firing sheds and fire-holes.

The sizes of Scotch kilns vary considerably. One (such as that shown in Figs. 37 to 42), 20 ft. long, 10

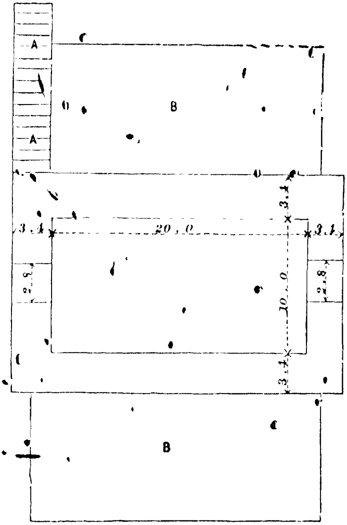

FIG. 38.—Plan of Scotch kiln, showing the roofs of the firing sheds (B, B), and the steps (A) leading to the top of the kiln.

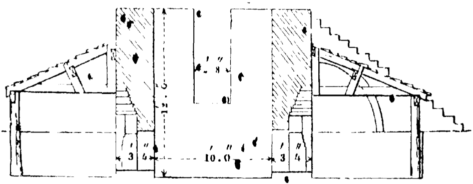

FIG. 39.—Cross-section of Scotch kiln, showing the construction of the fire-holes.

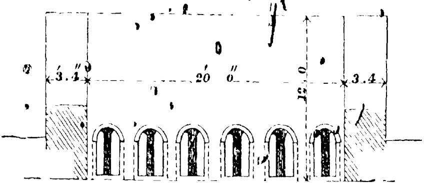

Fig. 40.—Longitudinal section of Scotch kiln, taken through the doorways at the ends of the kiln, and showing the inside of fire-holes.

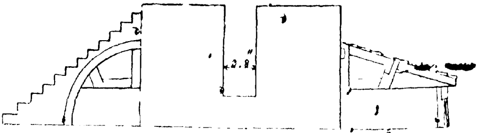

Fig. 41.—End elevation of Scotch kiln, showing doorway, ends of firing sheds, and steps leading to top of kiln.

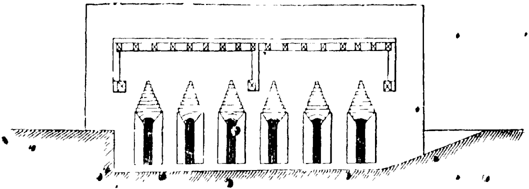

Fig. 42.—Side elevation of Scotch kiln, with the firing shed removed, in order to show the fire-holes.

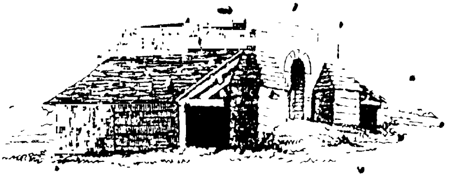

Fig. 42a.—Buttressed kiln.

wide, and 12 ft. high, will, with the addition of a parapet, burn 25,000 bricks at once, and will require rather more than that number of bricks for its erection. The cost of such a kiln would be from £30 to £50, excluding the value of the materials.

The capacity of a kiln may be roughly calculated on the assumption that ten bricks require a cubic foot of space in the kiln, but much, of course, will depend on the nature of the clay and the amount of shrinkage before burning.

A well-built kiln should last for many years with occasional repairs.

### PROCESS OF BRICKMAKING.

*Clay digging.*—The clay should be dug in the autumn, and collected in large heaps at the bottom of the slopes, to be mellowed by the winter frosts. These heaps are shown at B, in Fig. 24. The cost of this operation varies from 1*s.* 9*d.* to 2*s.* 3*d.* per 1000 bricks, according to the labour of getting the clay, and the distance to which it has to be wheeled.

*Tempering and Grinding.*—In the spring the clay should be turned over by spade labour, being at the same time well watered and trodden, though this last operation is frequently omitted. The pebbles and large lumps of limestone are picked out by hand, and the clay is then wheeled to the mill, and tipped into the hopper. Sometimes the clay, after being ground, is at once tempered for use on the floor beneath the rollers; but for the best bricks, it is allowed to ripen for some time.

The temperer is generally paid by the moulder, who contracts for tempering, moulding, and hacking at a price per 1000. The cost of tempering and grinding for common bricks is about 1s. 8*d.*, exclusive of the cost of horsing or driving the mill, which is borne by the proprietor of the yard.

One temperer with a horse-driven mill will keep one moulding-table constantly supplied, and will also assist the moulder in getting up his bricks from the floor.

*Moulding.*—A sufficient quantity of clay having been prepared on the tempering floor, one of the moulder's boys takes up as large a lump as he can conveniently carry, and, placing it on his head, takes it to the moulding-table, and walking up the sloping plank, deposits it at the end of the table, to the right hand of the moulder at B, Fig. 30.

The moulder having sprinkled some dry sand over the part of the table marked D, takes from the heap of tempered clay a piece sufficient to make a brick, and kneads this clot with his hands on the sanded part of the table, so as to bring it approximately into shape. He then raises the clot in the air, and dashes it with some force into the mould, striking off the superfluous clay with his fingers. He then dips his hands into the water-box, and, with very wet hands, works over the face of the brick, so as to force the clay perfectly into the mould in every part. He next takes the plane and passes it backwards and forwards with considerable pressure, until the face of the brick is flush with the edges of the mould, and then, reversing the mould, planes the underside in the same way. The brick being moulded, the moulder slides it on the wet table to his left-hand side, where it is taken off by a second boy, who carries it, mould and all, to an unoccupied part of the floor, where he turns it out carefully on one of its sides, and returns with the empty mould. Meanwhile the moulder has made another brick in a second mould, which is now ready to be taken off, and this process is repeated until the distance to an unoccupied part of the floor is too great to allow of the boy's returning in time, and the table is then shifted to another part of the floor.

*Drying.*—After the bricks have remained for a few hours in the position in which they were first placed on the floors, they are turned on their edges by a boy who turns up two at once, one with each hand. They remain in this position a few hours longer, and are then laid flat on the opposite side to that on which they were first placed. Careful moulders sprinkle sand over the wet bricks as they lie on the floor, so as to absorb the superabundant moisture, and render them less liable to crack; but this is not always done.

The new bricks sometimes also undergo a slight dressing with the clapper, or are pressed when half dry, to take off any roughness at the edges, and to correct any alteration of form which may have taken place on turning them out of the mould. In some cases, they are scraped with a small iron scraper, to remove any dirt that may adhere to them.

After lying flat a few hours longer, they are carried by the boys, three at a time, to the hovel, where the moulder builds them into hacks 50 bricks long and 14 courses high, each hack containing 700 bricks. As the bricks are hacked they are *batted* with the clapper, to correct any warping which may have taken place whilst lying on the floors. The bricks remain in the hovel until they are ready for burning.

The time allowed for drying varies with the weather, the size of the kiln, and the demand for bricks. Some brickmakers get the bricks out of the hovel within a fortnight of their leaving the moulds, but this haste is very prejudicial to the soundness of the bricks, and as a general rule, three weeks is the least time that should be allowed for drying.

The time that the raw bricks lie on the flats depends solely on the weather. In good drying weather the bricks are made one day and hacked the next; but at other times several days may elapse before they are fit for hacking.

It is not very easy to separate the cost of hacking from that of moulding, as both operations are performed by the moulder. The price for moulding, including tempering and hacking, is from 4*s.* 6*d.* per 1000 and upwards; 5*s.* is a common price.

A good moulder, if solely occupied in moulding, will turn out 2000 bricks in a day, between 6 A.M. and 6 P.M.; but as nearly one-third of the moulder's time is taken up with hacking, the average day's work is not more than about 1300 per day, or between 7000 and 8000 weekly.

The above description refers to the ordinary mode of proceeding, but for facing-bricks additional processes are employed. *Pressed bricks,* as their name implies, are prepared by putting the raw bricks one at a time, when nearly dry, into a metal mould, in which they are forcibly compressed by the action of a powerful lever which forces up the piston forming the bottom of the mould. This gives a very beautiful face to the brick and leaves the arrises very sharp, but bricks so prepared require a longer time for drying and judicious management in the kiln, otherwise they will be unsound, and when exposed to the weather will soon perish.

*Polished bricks* are rubbed on a bench plated with iron, to make their surfaces perfectly even, and are also dressed with a "dresser" as before described. This process is only applied to the best bricks, and its cost is such that it is not employed to any very great extent.

The contraction of the clay in drying is usually slight, and no perceptible diminution of size takes place in burning if the bricks have previously been thoroughly dried.

*Burning.*—The setting of the kiln is an operation on which much depends; it requires an experienced man, as there is a knack in arranging the bricks in a proper manner, to allow the heat to be diffused equally through the kiln, and to afford a proper draught, so as to obtain the greatest amount of steady heat with the smallest expenditure of fuel.

The lower part of the kiln is filled with common bricks, narrow openings being left, as shown by the dotted lines in Fig. 37, forming flues connecting the opposite fire-holes, the tops of these flues being formed by oversetting the bricks on each side till they meet. These flues are of the same height as the fire-holes.

The best bricks are placed in the middle of the kiln, and above these again are placed common bricks up to the top. The bricks are not placed close together, but a space is left all round each brick, to allow of the passage of the heat round it the bricks in the successive courses being crossed either slantwise, or at right angles to each other. When a brick rests partly on others, and is partly exposed to the fire, the exposed part will commonly be found of a lighter red than those to which the fire has had no access, and this is one great cause of the mottled colour of the Nottinghamshire bricks. When, therefore, it is wished to produce bricks of a uniform red tint, great care is taken to keep the faces and ends of the bricks in close contact, crossing them every few courses only.

The top of the kiln being finished, the doorways are built up with refuse bricks and plastered over with clay, to prevent the admission of currents of cold air. The fires are then lighted and the heat raised gradually, care being taken not to urge the fires until all the steam is driven off from the bricks, and the actual burning begins. When the fire has attained its full heat, the fire-holes are partially stopped with clay, and the top of the kiln is covered over with earth, turfs, or boards, to check the draught and a steady uniform heat is kept up until the completion of the burning, which generally occupies three days and three nights from the first lighting of the fires. At the expiration of this time the fire-holes are completely stopped, and the fires put out. The kiln should then be allowed to cool very gradually, as the soundness of the bricks is much deteriorated by the kiln being opened too soon.

The fuel employed is coal,[*] the quantity[†] used being about half a ton per 1000 bricks, the exact amount depending on the quality of the fuel and the judicious setting of the kiln. The cost of firing is low, as excellent coal can be obtained at the yards from 8*s.* 6*d.* per ton upwards. The small coal or *slack* frequently used in the early stage of burning does not cost more than 5*s.* to 6*s.* per ton.

The colour and soundness of the bricks vary according to their position in the kiln and the intensity of the heat to which they have been exposed. Those nearest the fire become partially vitrified, and of a blackish tint. Those which have been more favourably placed burn to various tints according to the nature of the clay, from red to straw colour and white, and when struck together ring with a clear metallic sound. Those which are underburned are tender, of a pale red colour, and give a dull sound when struck together.

The cost of setting and drawing the kiln is generally reckoned at 2*s.* 0*d.* per 1000, this including stacking the bricks in the yard, or placing them in the carts of the purchasers. If, however, they are not for immediate sale, an additional 6*d.* is charged for loading the carts from the stacks.

The labour in firing is reckoned at 1*s.* to 1*s.* 6*d.* per 1000 bricks.

*Land and Brick-earth.*—The proprietor of a brickworks usually rents the necessary land at a price per acre, and in addition pays for all clay removed at a set price, whatever its quality.

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[*] Soft coal or small coal is preferred.

[†] In some brickyards much coal is wasted on the top of the kiln. As the heat has always an upward tendency, the coal burned on the top of the kiln has very little effect on the bricks, and most of it is wasted in smoke and flame.

As the brick-earth is exhausted, or the workings reach an inconvenient depth, the ground is levelled and again thrown into cultivation. This is, of course, done at the earliest period possible; and in some cases the rental of the land is nearly made up by the profit derived from cultivating the site of the exhausted workings, so that it is impossible to give an accurate estimate of the proportion which the rental of the land bears to the total cost of manufacture, as it must vary widely in each particular case. This remark does not hold good with regard to the brick-earth, which is paid for at the rate of 8*d.* per cubic yard, or 2*s.* per 1000 bricks, a thousand bricks requiring about 3 cubic yards of clay. The rates vary greatly, and some brickmakers only pay about half the figures mentioned.

It must be remembered that, as above stated, this price is paid for all clay removed, whether suitable or not for brickmaking. For common bricks the earth is taken as it comes, good and bad being ground up together; the cost of grinding being less than the loss which would result from the rejection of the inferior earths. For front bricks and other best qualities, the clay is carefully picked, and the cost is proportionately increased thereby (see p. 117).

No estimate can be given for the amount of land required for making a given number of bricks, as it depends on the situation of the yard, the depth to which the workings can be carried, and the nature of the "clay."

*Buildings and Machinery.*—From the circumstance that in existing yards the buildings have been erected at different times without any very systematic plan, it is not very easy to ascertain what are the best relative sizes of working floors, hovels and kilns, or what extent of building and plant are required for working a yard to the greatest advantage. Unless the manufacture be conducted on a very large scale, the grinding mill will, in most cases, often be unemployed; and the wash-mill being used only in the manufacture of arch bricks, it is only in the immediate neighbourhood of a large town that a return for the cost of its erection can be hoped for. It will always be found an advantage to have an excess of shed-room rather than the contrary.

The following rough estimate will give an idea of the buildings and machinery required for a new yard, to produce from 40,000 to 50,000 per week:—

1 mill for crushing the clay.

120 yards lineal of hovel, 6 yards wide.

1200 square yards of working floor.

This extent of hovel and floor will be sufficient for the operations of six moulders; and, taking the work of each moulder to average throughout the season 1300 per diem, the week's work of the six moulders would produce 46,800 per week, or in round figures 140,000 every three weeks.

This rate of production would render necessary two kilns, each to burn 35,000, and these kilns would be kept in constant activity, each kiln being fired twice every three weeks.

For a yard in which it is proposed to make all kinds of bricks the following additional buildings will be required:—

Cellars for ripening the ground clay (if desired);

A tempering shed, for tempering under cover;

One or more drying-houses, provided with furnaces and flues;

A wash-mill for treating the clay for making rubbers, arch bricks, etc.

Besides the above erections, stabling will be required to a greater or less extent in all yards; also a cottage; sheds and outbuildings for keeping tools, carts, and implements.

*Tools.*—The tools required by each moulder are a pair of brass moulds, a moulding-table, and appurtenances complete, a plane and a clapper (see p. 132).

In addition to these implements a variety of other articles are required, as shovels, picks, barrows, planks, sand baskets, sieves, etc., which are kept in store and supplied to the men as required.

The proprietor of the yard finds all tools and implements, sand, coals, and horses for the mills.

*Labour.*—The general management of the yard is usually under a "contractor," who superintends the yard and contracts with the proprietor for all the labour required in the actual manufacture, at a price per 1000 on the number of bricks delivered from the kiln, the contractor bearing all loss from frost, wet, or other causes.

The contractor may sublet the moulding to a moulder, at a price per 1000, to mould and hack the bricks ready for setting in the kiln; the moulder employing two boys to assist him in moulding and hacking, and also a temperer, who tempers the clay for him, and assists in lifting the bricks from the floor.

The first turning over of the clay is performed by labourers, under the direction of the contractor, who, with the assistance of a few boys and labourers, usually sets and draws the kilns himself, and attends to the burning.

The cost of manufacture may be summarized as follows:—

| | Per 1000 bricks £ | s. | d. |
|---|---|---|---|
| Clay digging | 0 | 2 | 0 |
| Turning over and watering clay and feeding mill | 0 | 0 | 8 |
| Grinding | 0 | 0 | 6 |
| Tempering for moulder | 0 | 0 | 4 |
| Moulding, drying and hacking | 0 | 5 | 0 |
| Setting and drawing kiln | 0 | 2 | 0 |
| Burning | 0 | 1 | 6 |
| Total cost of labour | 0 | 12 | 0 |
| Coal, half a ton, at 10s | 0 | 5 | 0 |
| Clay (royalty) | 0 | 2 | 0 |
| Rent, tools, interest on capital, etc. | 0 | 3 | 0 |
| Total cost at yard | 1 | 2 | 0 |

The relative values of the different qualities of brick may be thus stated:—

| | | £ | s. | d. |
|---|---|---|---|---|
| Common bricks (the clay not picked) | per 1000 | 1 | 5 | 0 |
| Front bricks (made in copper moulds, the clay having been picked) | " | 1 | 10 | 0 |
| Polished bricks (made in copper moulds, the earth selected with care, and the bricks dressed on a bench) | " | 2 | 10 | 0 |

The serious competition of machine-made bricks in the large towns has made the manufacture of hand-made common bricks unprofitable except in limited areas.

# CHAPTER VI

## HAND BRICKMAKING AS PRACTISED IN STAFFORDSHIRE

In Staffordshire, red, blue and drab bricks are made for building purposes, also "blue bricks" for paving. The latter are sometimes termed "dust bricks" from the coal-dust used when they are moulded. When fired these blue bricks have a smooth and somewhat glossy surface, and, being very durable, are extensively used.

The drab bricks are used to a limited extent for building, but more generally as fire-bricks by potters and iron-masters; though they are inferior to the Stourbridge bricks, and the latter are preferred where intense heat is generated.

*Clays.*—Both blue and red bricks are obtained from the same material, the red variety being produced at a lower temperature than that needed for blue bricks. For the latter half a ton more coal and two hours more time is allowed per kiln. The clays or marls are selected for the purposes to which they are best adapted.

Marls and clays suitable for brickmaking are plentiful, and of several varieties, in this neighbourhood, but the most extensive bed of red marl runs in an almost unbroken line through this country from south to north, and generally west of the great coalfield. It is worked with the same results at Stourbridge, Tipton, Hanford, Basford, Tunstall, and other places. A reference to a geological map of the country will show the peculiarity of this long bed of stratified marls.

In the Potteries there are about ten distinct sorts of strata. The following names are given to the seven sorts most used; and their position with relation to the earth's surface is shown by the order of their names here given:—(1) Top red marl, (2) dun coloured, (3) top yellow, (4) mingled, (5) bottom yellow, (6) brown, and (7) bottom grey. A "rotten red" stratum occurs between 3 and 4, but is not used.

Several of these marls vary but slightly in their chemical composition, and, when used, at least three sorts are generally mixed together.

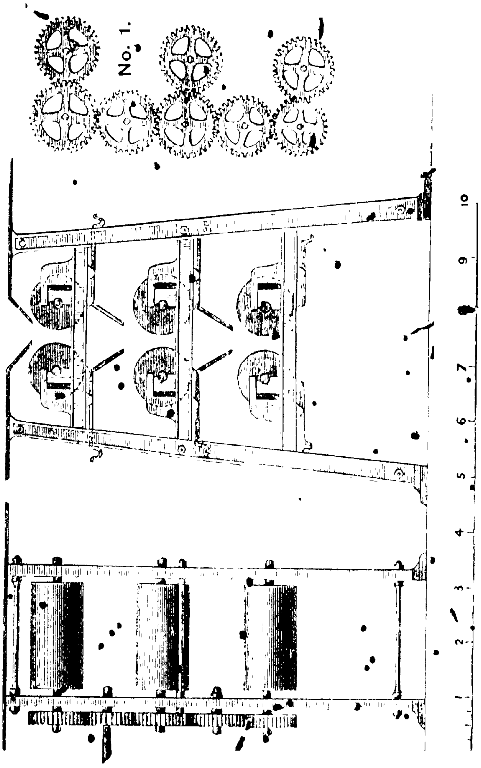
The marls have an average contraction when mixed of 1 in 10; that is, a 10-in. mould gives a 9-in. brick when fired, although some of the varieties used separately contract 1 in 6.

*Buildings and Plant.*—The yard, with the ground opened for work, should have the following buildings and machinery upon it, for a weekly output of 100,000 bricks:—

A steam engine;
A set of horizontal rollers;
A pug-mill;
Six drying-houses;
Nine kilns.

The drying-houses should measure about 25 yards in length by 6 yards in width, and have two flues under the floor through their entire length.

*Tempering.*—The marls are dug and are then placed in a hopper over the topmost rollers (Figs. 43 to 45), and passing successively through the three



Machine, with three pairs of rollers, for grinding marl.
IG. 43.—Side elevation. FIG. 44.—Front elevation, with the gearing removed.
FIG. 45.—Elevation of gearing, No. 1 being the driving-wheel.

## ANALYSES OF STAFFORDSHIRE MARLS AND CLAYS.

A, B, C, D, E and F from Basford; G and H from the Staffordshire Potteries.
By F. C. Wrightson, Esq., Birmingham *

| | Red marl, which burns blue | Dun-coloured marl, burns good blue. | Top yellow marl, burns reddish-blue | Mingled marl, burns blue-reddish | Rotten red marl, will not stand the heat, it melts | Mixture of clays, Nos 1, 2, 3, and 4, burns good blue. | Clay from Stoke-upon-Trent, burns red, and will not burn blue. | Sagger marl, burns light buff—a firebrick. |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H |
| Silica . . . . . . . | 69·87 | 64·32 | 65·78 | 70·17 | 42·84 | 59·44 | 60·02 | 54·38 |
| Alumina . . . . . | 16·79 | 20·33 | 15·16 | 16·25 | 17·61 | 25·93 | 24·26 | 26·55 |
| Oxide of iron . . . . . | 8·88 | 10·86 | 8·49 | 8·41 | 6·97 | 10·74 | 9·14 | 8·38 |
| Lime . . . . . . . . | Trace. | Trace. | 1·67 | 1·29 | 15·36 | — | 1·66 | — |
| Carbonic acid . . . . . | — | — | — | — | 11·61 | — | — | 3·14 |
| Oxide of manganese . . . | — | — | — | — | 2·20 | Trace. | Trace. | — |
| Soda and a little potash . . | — | — | — | — | — | — | 1·40 | — |
| Water . . . . . . . . | 4·26 | 6·60 | 5·37 | 5·86 | 3·94 | 3·11 | 3·89 | 7·28 |
| | 99·80 | 102·11 | 96·47 | 101·98 | 100·53 | 99·22 | 100·31 | 99·73 |

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* There are some curious anomalies in some of these results, but as these do not affect the general value of the Table, it is retained as of historical interest.—[Reviser's Note ]

pairs, the crushed material is deposited on a floor below. It is then wheeled away, and mixed together with a proper quantity of water, by spade labour, or is passed through the pug-mill; but if required for ordinary bricks, the ground marls may be mixed with marls that have been weathered but not ground, and may then be tempered by spade labour until the proper degree of plasticity is obtained. It is, however, best to crush the whole of the material, and to pass it all through a pug-mill.

*Moulding.*—The bricks are moulded by the slop-moulding process (p. 38), at the rate of 3000 per day; the price paid for tempering and moulding being about 7*s.* 0*d.* per 1000. The process is as follows: the temperer wheels the prepared material in a barrow up a plank, and empties it upon the moulding-table (Fig. 46). The moulder having sprinkled sand from the box (A), upon the moulding-board, and upon that part of the table where the clot is moulded, takes as much clay as will fill the mould, and by a quick roll and a tap gives the clot an approximate form to the mould; he then lifts up this lump of clay about 12 in. high, and throws it forcibly into the mould, pressing it down with both hands to fill all the cavities, and strikes off the surplus with a wooden strike, which he throws into a small water-box (D), in front of him after each time of using. An attendant boy, who has previously dipped a mould in a water-trough (B), by the side of the table, places it on the table ready for the moulder, and carrying away the moulded brick in the mould, carefully empties it on its flat side on the floor. These operations are repeated until the floor is filled, when the moulding-table is removed to a second floor.

The mould used differs greatly from those described in earlier chapters. It is made of oak, and the edges are plated with iron.

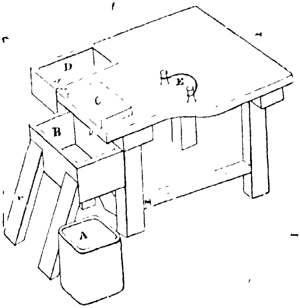

FIG. 46.—Moulding-table.

A. Sand-box. B. Water-box for washing moulds. C, Moulding-board. D. Water-box for strike. E. Clay knife.

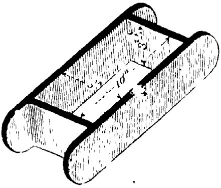

FIG. 47.—Staffordshire brick mould.

*Drying.*—The floors are of different sizes; a convenient one is 25 yards in length by 6 yards in breadth, which will hold 3000 bricks. Here they are allowed to dry until sufficiently hard to handle and place in hacks, the length of time depending upon the weather. In quick-drying weather the bricks will remain half a day as deposited from the mould, and half a day turned upon edge, and afterward they are placed up in hacks, where they remain until placed in the kiln. Owing to the damage suffered by hacking, some firms prefer to complete the drying on steam or fire-heated floors. Many blue bricks are repressed when partly dry so as to give them a better shape.

*Burning.*—The kiln is usually of the Newcastle type (Fig. 53), or of a circular form with up-draught. The latter (Figs. 48 to 51), will contain 8000 bricks, which are so placed as to allow a space between the sides of each for action of heat, and an equal diffusion thereof. When the kiln is full, the clammins or doorway is made up, and the fires kindled and kept burning 36 hours for red, and 48 hours for blue bricks,* consuming 3 tons of coals for the former, and 4 tons for the latter. The expense of setting, firing, and drawing a circular kiln of this type containing 8000 bricks is: labour 26*s.*; coals £1 16*s.* The costs of working a Newcastle kiln are about the same rate per 1000 bricks.

For burning red bricks, muffle kilns are sometimes used so as to secure a better colour.

Recently, continuous kilns of special design have been employed in the manufacture of blue bricks, with a saving of more than half the fuel formerly used.

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* Blue bricks are finished with a diminished air-supply so as to reduce the iron oxides. Salt is sometimes thrown into the kiln before closing.

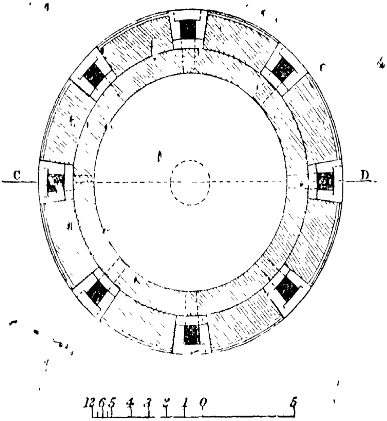

FIG. 48.—Plan of kiln taken at top of fire-holes at level AB, Fig. 49.

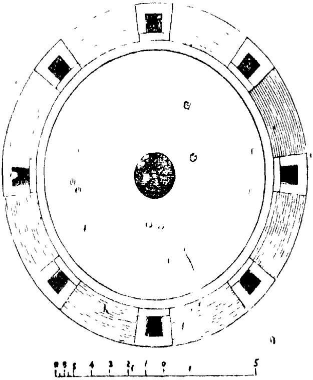

FIG. 49.—Plan of kiln, looking down on top of oven

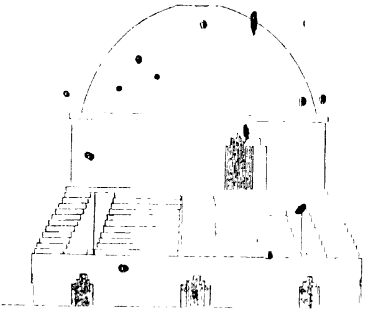

FIG. 50.—Elevation of kiln

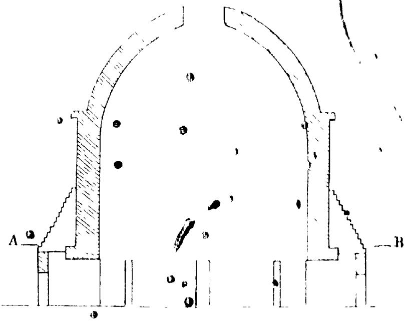

FIG. 51.—Section of kiln, on line CD, Fig. 48.

*Cost of Manufacture.*—The details of the cost of manufacture are as follows:—

| | Per 1000 bricks. | | |
|---|---|---|---|
| | £ | s. | d. |
| Clay getting | 0 | 2 | 0 |
| Tempering and moulding | 0 | 7 | 0 |
| Setting oven firing and drawing | 0 | 3 | 3 |
| Coals | 0 | 1 | 6 |
| Rent, royalty, interest on capital, repairs, contingencies, etc. | 0 | 4 | 0 |
| | 1 | 0 | 9 |

Owing to the enormous quantities of blue bricks used in recent years, hand-brickmaking has been largely replaced by mechanical methods. This is the more necessary as some of the excavations are very deep. The plant generally used is shown in Fig. 52, but the bricks are usually repressed before they are quite dry (Chap. VIII.) for better-class work. This gives them a sharper arris and produces more regular brickwork of greater strength.

## CHAPTER VII.

### FIREBRICKS

FIREBRICKS are made from (1) refractory clays from the Coal Measures, (2) siliceous rocks, (3) siliceous sands, etc., and are used in those parts of furnaces which would destroy ordinary bricks.

The chief requisite is that the material must be capable of resisting the very high temperatures reached in some industries. Hence it must be almost free from lime, magnesia, iron oxide, pyrites and alkalies, as these materials act as fluxes and at

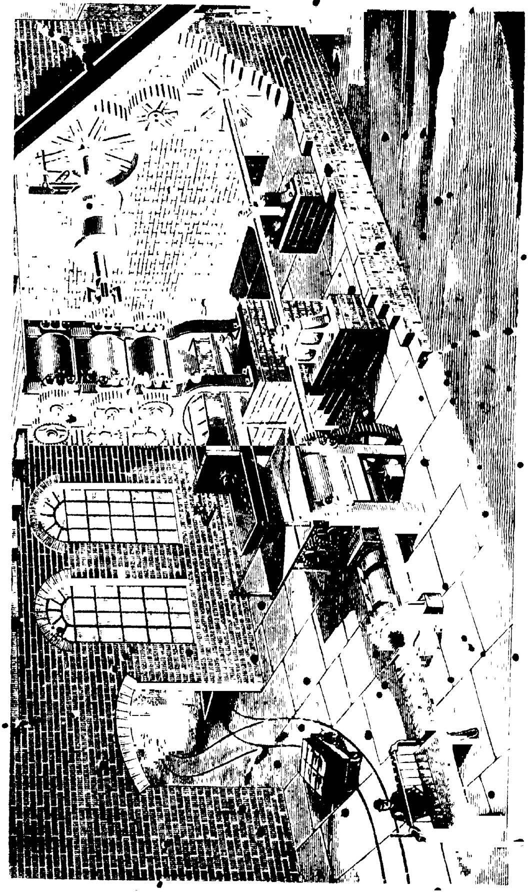

FIG. 52.—Plant used in the manufacture of blue bricks by machinery.

sufficiently high temperatures will effect the partial fusion of the clay.

Analysis will only show the heat-resisting power of a clay to a very limited extent, so that a better means of ascertaining the refractoriness of a given clay is to determine its "softening point" by comparing its behaviour with that of Seger cones. For refractory purposes, a clay when made into the shape of a Seger cone should not bend at a lower temperature than is required to bend Seger cone 26.

The "clunches" or deep mine fireclays are in the nature of shales or rock, and require to be crushed to powder, usually by powerful edge-runner mills (p. 175), before they can be made into a plastic paste in a pug-mill. The carefully pugged paste is then moulded by the slop process (p. 157) in a manner similar to that used in Staffordshire (Chap. VI.). The bricks are dried on steam or flue-heated floors or hovels (pp. 119, 134), and are burned in round down-draught kilns or in kilns of the Newcastle type (Fig. 53) at a temperature of 1310° to 1800° C. (see p. 48).

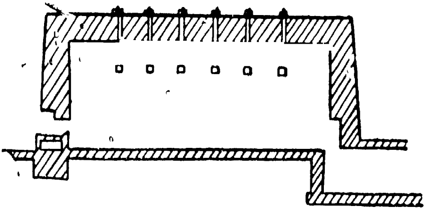

FIG. 53.—Section of Newcastle kiln.

In order to enable the bricks to resist sudden changes in temperature, burned fireclay or "grog" in the form of a very coarse powder is sometimes mixed with the raw clay.

The most celebrated fireclays are found in the neighbourhood of Stourbridge in Staffordshire, Leeds and Halifax in Yorkshire, Newcastle, Durham and Kilmainock and Gartcosh in West Scotland.

Firebricks are also made of almost pure silica, but it is erroneous to term this "clay." The material termed *clay*, found in the Vale of Neath and used for making Dinas firebricks is so nearly pure silica that it is entirely destitute of plasticity. It lies on the limestone and occasionally intermixes with it, and contains only about 5 per cent. of non-siliceous matter. The bricks have extraordinary fire-proof qualities, but are somewhat sensitive. The material had long been used as a sand, and many attempts were made to form it into bricks; without success, until a method was contrived by W. W. Young, and in 1822 a company was formed for the manufacture of these bricks. The mode of making the Dinas bricks was long kept secret, but the following is that used at the present time in the district:—

The rock is crushed to coarse powder between iron rolls; it softens by exposure to the air, but some of it is too hard to be used. The powder of the rock is mixed with about 1 per cent. of lime and sufficient water to make it cohere slightly by pressure. This mixture is pressed into iron moulds, of which two are fixed under one press, side by side. The mould, which is open at the top and bottom, like ordinary brick-moulds, is closed below by a movable iron plate, and above by another plate of iron, which fits in like a piston, and is connected with a lever. The machine being adjusted, the coarse mixture is put into the moulds by a workman, whose hands are protected by stout gloves, as the sharp edges of the fragments would otherwise wound them; the piston is then pressed down, after which the movable bed of iron on which the brick is formed is lowered and taken away with the brick upon it, as it is not sufficiently solid to admit of being carried in the usual manner. The bricks are dried on these plates upon floors warmed by flues passing underneath; and when dry they are piled in a circular closed kiln covered with a dome, similar to kilns in which common firebricks are burned. About seven days of hard firing are required for these bricks, and about the same time for the cooling of the kiln. One kiln contains 12,000 to 32,000 bricks, and consumes about 1¼ tons of coal per 1000 bricks. The fracture of one of these bricks shows irregular particles of quartz, and the lime which is added acts as a flux, causing them to agglutinate. These bricks *expand* on heating, while bricks made of fireclay *contract*. Hence they are useful for the roofs of reverberatory furnaces, and for parts where solid and compact lining is required. These siliceous bricks must not be exposed to the action of slags rich in metallic oxides or to sudden changes in temperature.

A similar method is used in the manufacture of *ganister bricks*, which possess similar properties. The rock must be ground before it can be used, but as ganister contains a small proportion of clay, no addition of lime is necessary.

In Derbyshire and some other districts—as at Epsom and Windsor—clayey sands occur, and are used for manufacturing firebricks. They are made into a paste with water in a pan mill, and the paste so produced is made into bricks in a manner similar to fireclay.

Although the methods used in the manufacture of firebricks are simple and easy to comprehend, the variations in the quality of the raw material and in the action of the fire in the kiln cause considerable difficulty in actual working. The relative sizes of the different grains of clay and non-plastic material require very careful consideration, and any one entering upon the manufacture of firebricks without previous practical experience would find that the technical difficulties involved in producing bricks capable of resisting the required variations in temperature are very great. The methods used to overcome these are outside the scope of a rudimentary treatise, but some further details will be found in the reviser's "Modern Brickmaking."

# CHAPTER VIII

## ON THE MANUFACTURE OF BRICKS BY MACHINERY

IT will usually be found that if a sufficient number of skilled brickmakers can be obtained, the use of machinery to mould the bricks effects no appreciable saving. Unfortunately, the number of skilled brick-moulders is very small, and the demand for bricks has, for some years, been far greater than these men can supply. It has, therefore, been necessary to devise means of replacing human labour by mechanical appliances, particularly where very large numbers of bricks are needed in a short time, as in the erection of public buildings or in large engineering enterprises.

The increased demand for bricks of more accurate shape than those ordinarily made by hand has also necessitated the use of more powerful presses, and the ever-growing tendency to reduce the number of processes employed in brickmaking has brought about the introduction of a variety of "systems," each of which has its own advocates.

It has been much discussed by practical men, whether bricks moulded under great pressure are better than those moulded by hand in the ordinary way. They are of denser texture, harder, smoother, heavier, and stronger than common bricks. On the other hand, it is difficult to dry them, because the surfaces become over-dried and scale off before the evaporation from the centre is completed. Their smoothness lessens their adhesion to mortar; and their weight increases the cost of carriage, and renders it impossible for a bricklayer to lay as many in a given time as hand-moulded bricks. On the whole, therefore, increased density may be considered as a disadvantage, although, for some purposes, dense bricks are very valuable. Yet, in spite of this, the number of machine-made bricks continues to increase, and the proportion of the lighter hand-made bricks to the whole output is smaller now than ever before, in spite of the present fashion of south-country architects to employ them in preference to machine-made bricks.

It is not intended, in this chapter, to give detailed descriptions of the machines employed by brickmakers at the present day; the object of an elementary work of this kind being to deal with the broad outlines of the art rather than with a multiplicity of details.

For the same reason it would be highly out of place that within the limits of an "outline" such as this volume there should be any appraising of the relative merits or demerits of the various machines mentioned—as it is impossible within so small a compass to treat the subject in the exhaustive manner that alone would justify such criticism.

The following notices must, therefore, be viewed as merely collecting before the reader, with sufficient illustrations, a few of the more prominent processes in use in Great Britain, sufficient to serve as an index to those specially interested, whereby more complete information may be obtained from the advertisements in the various trade journals or by reference to more advanced works on the subject, such as "Modern Brickmaking," by the reviser of the present volume.

The trade in producing brick machinery has come to be a very large one, in which great intelligence, energy, and capital have been invested, and from which have emanated an immense number of inventions, chiefly the subjects of patents.

It is, however, remarkable that, out of the many patents granted for the manufacture of bricks by machinery, only a few are in extensive use at the present time, and these are of comparatively recent date. Thus, of all the machines described in the previous edition of this "Treatise," scarcely any are at work to-day!

Perhaps the most notable feature of the introduction of machinery to brickmaking is the facility it offers to the utilization of many materials never previously used for the purpose. This is due to the fact that whilst the natural clays are occasionally found in a state capable of being at once made into bricks, yet they must usually be subjected to more or less disintegration, grinding, and mixing into a plastic paste before being employed, and the shales—which now form an invaluable brickmaking material—can only be used when powerful crushing and mixing machinery is available.

Methods of freeing the material from adventitious matter are much more effective when machinery is available, and this fact enables many clays—otherwise unsuitable—to be profitably used.

Having installed machinery for the preparation of a clay paste, it is only natural that its use should be extended to the shaping of the bricks, though the latter is by no means necessary.

Thus, it would be quite possible to apply machinery for the preparation of a suitable paste from shales and very tough clays, and to shape this paste by hand-moulding, as described in previous chapters, but this method is seldom adopted except in the manufacture of firebricks. For ordinary building bricks the paste is shaped by mechanical means to be described later.

In some districts (Chap. IX.) the production of a paste is avoided altogether and the powdered material is compressed into bricks in extremely powerful presses. This reduces the amount of drying necessary, and has certain other advantages, though the bricks so made are by no means so popular or so durable as those produced from plastic paste.

The final result of the application of machinery and of continuous kilns has been materially to reduce the cost of manufacturing bricks, so that in spite of the heavy interest and depreciation charges on the machinery employed, bricks can now be produced from difficult materials at a distinctly less rate than from the most suitable materials by the old method of tempering and hand-moulding. Unfortunately, lower selling prices have rendered the profits much smaller than in former years.

Brick machinery may be conveniently divided into two chief groups, of which the first comprises all that used in the preparation of the material, whilst the second group consists of the mechanical appliances used to shape the bricks.

## DRY *v.* PLASTIC PROCESSES.

Each of these groups may be sub-divided into four classes or processes according as the material is moulded, (*a*) in a plastic state, (*b*) a stiff-plastic state, (*c*) a semi-dry condition, and (*d*) in the form of a dry powder or "dust."

The plastic processes have the advantage of producing a better quality of brick, but the cost of drying is considerable, and, in cases where competition is keen, quality must, to some extent, be sacrificed to price.

The most salient advantages of the drier method are that it produces a less porous brick of perfect shape, and one that shrinks less both in drying and in burning, than do those made in a more plastic state; and that a certain amount of the labour and cost of the preliminary preparation of the clay is saved. Some of the disadvantages are that, unless the clay in the dry or merely damp state be scrupulously well prepared, and unless a degree of pressure be employed which demands much power, the bricks may be deficient in tenacity and in uniform solidity, or even in accuracy of shape (see pp. 116, 135). With certain clays and excessive pressures, bricks are produced, which, though dense and resistant, have so *un*porous a surface as hardly to make bond with either cement or mortar.

The "stiff-plastic" and the "semi-dry" processes (p. 190) being intermediate between the others, possess some of their advantages or disadvantages according to the nature of the clay and the extent to which its plasticity is developed.

On the whole, the "wire-cut" and the "stiff-plastic" processes appear likely to be the most popular in the future, though large numbers of bricks have been and are being made by semi-dry processes.

## MACHINERY FOR PREPARING CLAY

The machinery employed for preparing clays may be conveniently divided into two classes—as already mentioned—according as the bricks are to be moulded from a plastic or stiff-plastic material, or from a dry or semi-dry powder.

If a *plastic paste* is to be produced, the material must usually be passed through crushing rolls or ground in an edge-runner mill with solid pan so as to reduce any stones or hard lumps into a sufficiently fine state. The material must then be mixed with water, and pugged into a uniform mass of a pasty consistency. The amount of water added will determine the stiffness or softness of the paste.

If a clay contains much gravel or small stones, which must be removed and not simply crushed and mixed with it, the material must be roughly pugged and passed through some form of "clay cleaner," or it must be washed (p. 70). A "*clay cleaner*" is really a form of sieve, so strongly constructed that the soft clay may be forced through the apertures whilst the gravel and small stones remain behind. For small quantities a perforated steel plate may be attached to the mouth of a powerful pug-mill or to a "stupid," but for larger quantities a Bohn cleaner or similar appliance should be used.

If a *dry or powdered clay* is required the raw material must be of such a nature that it forms such a powder when crushed. Tough clays—being naturally plastic—must be dried before they could be ground, so that "dry processes" are chiefly applicable to shales and rock-clays.

The machinery used for grinding clays or shales to powder consists almost exclusively of edge-runner mills (p. 175) with the usual screens and other accessories. If the raw material is very hard and in large lumps, a preliminary treatment in a stonebreaker is desirable.

*Crushing Rolls.*—For reducing naturally plastic clays and for crushing small stones contained in them, crushing rolls are usually employed. These consist of a pair of smooth iron or steel cylinders somewhat resembling the domestic mangle or clothes wringer, but the rolls are placed side by side. Various devices are used for special clays, but the rolls shown in Fig. 27 are typical of those generally employed. Instead of a single pair of rolls it is not unusual to employ two or even three pairs for very hard clays or where the material is sticky and difficult to crush, as in Staffordshire (p. 155). When several rolls are used, the uppermost pair is usually grooved or provided with teeth. The upper pairs are set slightly apart, but the lowest pairs are set so as to almost touch each other.

The rollers are driven at different speeds, so as to produce a *rub* as well as a mere squeeze between the surfaces, and so better disintegrate the clay. The rollers are usually made about 20 in. diameter, and about 3 ft. long. They are fed by hand, through a hopper at top.

The framework and rollers must be very strongly built, as the power needed to crush flint pebbles and similar materials is very great. For this reason, horse-driven rolls (Fig. 27) are now seldom seen in this country.

*Edge-runner Mills* consist of a pair of grinding discs (Fig. 54) working on a bed or pan. The pan may be fixed: in which case the gearing is so arranged that runners are made to rotate and to travel forward at the same time. Mills of this type are much used for shales of exceptional hardness, and for clays containing limestone.

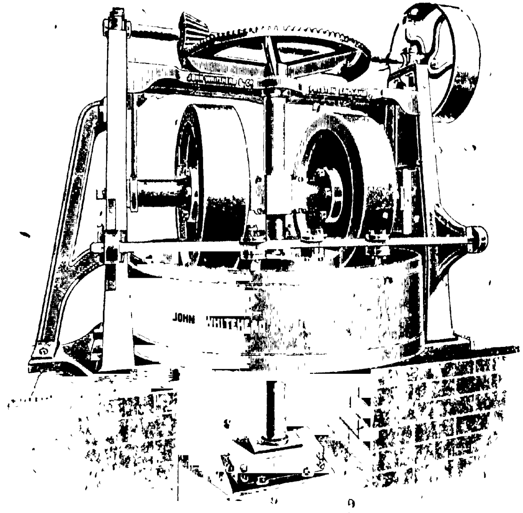

FIG. 54.—Edge-runner grinding mill.

Revolving pans are, however, becoming increasingly popular as they possess several advantages. In this case, the axis of the runners does not move horizontally, nor is any power transmitted directly to the runners. The friction produced by the movement of the material on the revolving pan is sufficient to cause the rapid rotation of the runners or discs as indicated by the arrows in Fig. 54A. It will be noted that the axis of the runners is free to rise and fall slightly by means of the slotted bearing at its ends. The method of driving the pan from below (under-driving) is now seldom employed, as it is more advantageous to keep the driving mechanism above the runners as in Figs. 54 and 55. With both fixed and revolving pans, scrapers are provided to turn the material over and to keep it fed to the runners. The

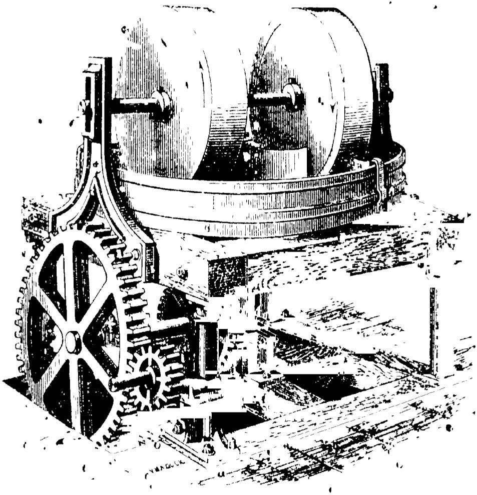

FIG. 54A.—Under-driven grinding mill.

adjustment of these scrapers requires frequent attention if the best results are to be obtained.

The bed or "pan" of an edge-runner mill may be either solid or perforated. The former is used when the materials are to be mixed rather than ground, as when a pasty clay is being treated. Perforated pans may have small circular perforations from $\frac{1}{16}$th to $\frac{1}{2}$ in. diameter, or they may be provided with slots about 6 in. long by $\frac{1}{4}$ in. to 1 in wide. For some clays the pan is replaced by a grating, so that the material fed to the mill is simply forced through the apertures. These perforations or slots may extend over the whole area of the pan or be confined to one portion of it.

The runners are usually of equal size and are mounted at equal distances from the centre of the pan, but for some clays it is found advantageous to have one small, wide roller and another large, narrow one, and to fix them excentrically so that they travel over different areas of the pan.

The material passing through the perforated or slotted pan of a mill in the form of a coarse powder may be received on a plate from which it is discharged by a scraper attached to the under side of the pan and revolving with it, or an open base mill (Fig. 35) may be used. The latter has several advantages where sufficient depth exists for the construction of the brickwork base.

From the outlet of the collecting plate or from the base of the mill, the powdered clay is carried by a bucket elevator (Fig. 55) to the screen, where the coarse material is returned to the mill and the fine is sent to the pug-mill or mixer.

If the product of the mill is in a plastic, pasty state it is usually allowed to fall into crushing rolls or is removed by a special form of shovel.

The material which has been treated in an edge-runner mill may be in one of three forms: (*a*) a plastic paste—due to its being worked in a moist condition on a solid pan, (*b*) a series of plastic fragments—due to its being worked in a moist state on a perforated

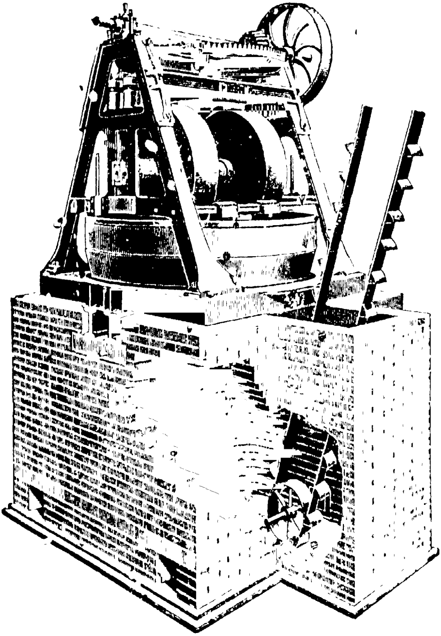

FIG. 55.—Edge-runner mill with open base.

pan or grid, and (c) a coarse powder—due to dry material being ground on a perforated pan or grid. According to its condition and the further treatment to which it must be subjected, the material, if plastic, is passed on to crushing rolls or to a pug-mill, or, if in powder, it is usually taken to a screen or riddle by means of an elevator.

This screen is of such a mesh that all the material sufficiently fine to be used passes through it, but the coarser particles pass over and are returned to the mill to be recrushed. The mesh of the screen varies with different clays, but most riddles used for this purpose have 8 to 14 holes per linear inch. Clay in a plastic state cannot be screened in this manner, so that the chief use of edge-runner mills is in the grinding of shales and rock-clays, which do not become plastic until they are mixed with water.

Clays which are plastic and contain limestone, and those in which an exceptionally uniform composition is required, are sometimes treated with water in an edge-runner mill with a solid, revolving pan (termed a "pan-mill"). This effects a much more intense rubbing action than can be obtained by any other mechanism, but is costly, as the mill must usually be emptied before another charge can be added. There are, however, some "continuous action" mills of this type now in use.

The *wet pan* or pan-mill just mentioned is simply a solid bottomed revolving pan of similar construction to those used for dry grinding, into which the clay is thrown in 8 to 12 cwt. charges, together with a suitable quantity of water, and is crushed and tempered into a plastic paste without the necessity for screening or pugging. Sometimes wet pans are used exclusively for tempering, and are then fed with material which has been crushed in another form of mill.

Wet pans unquestionably develop more plasticity and effect a better tempering than any other machine, but they are costly to install and in power—three or four pans being only equivalent to one pug-mill. In addition to this they require more skill on the part of the attendant, or the different patches of clay will be unequal in quality and stiffness.

*Pug-mills.*—These usually form part of the brickmaking machine, but may be kept quite distinct, if necessary. They consist of an outer casing and an internal shaft carrying blades or knives to cut and mix the clay. Where only a light pugging is needed the shape of the knives is of small importance, but where difficult clays are to be treated the shape and arrangement of the blades become a serious matter, though too complex to be dealt with in detail here. The pug-mills used in former days (Fig 12) are only effective for certain clays; for others more powerful mills in which the blades are broader, shorter, stronger and of a different shape are required. They are usually arranged somewhat in the form of a screw thread—four blades form a complete "turn"—but this form must not be maintained too closely, or the clay will be propelled forward without being well mixed.

In most brickworks the pug-mill is horizontal (Fig. 56), but vertical ones (Fig. 57) are used in a few red-brick works and in many of those making fire-bricks.

*Mixers*, or open pug-mills of the horizontal type (Fig. 58), are used where clays require an exceptional

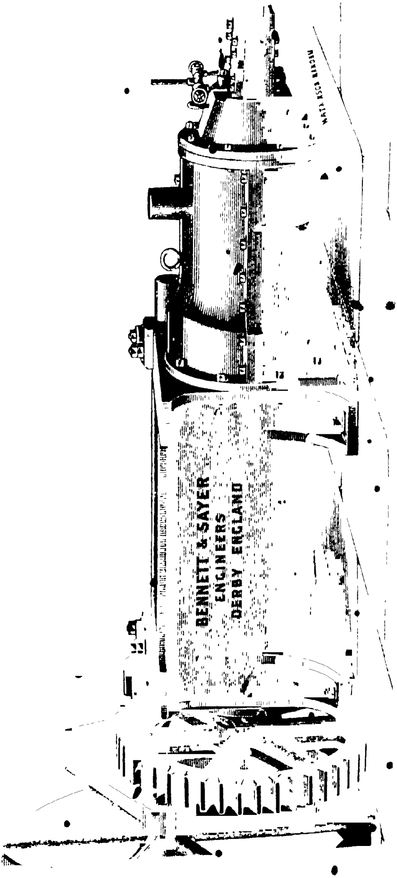

FIG. 56.—Horizontal brick machine.

amount of pugging. In general construction they so closely resemble ordinary pug-mills as to need no

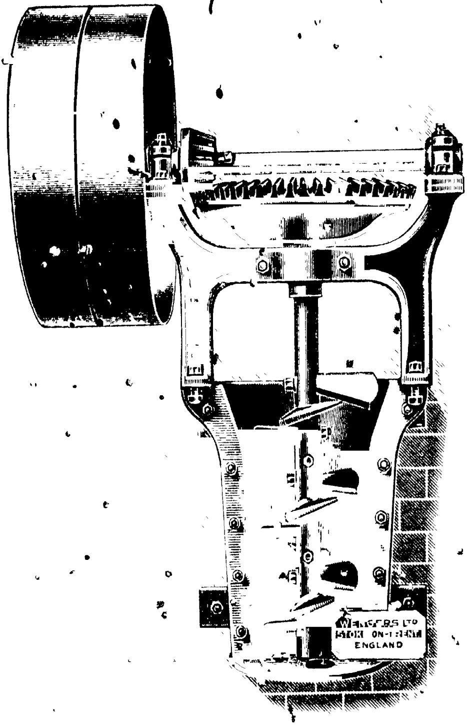

FIG. 57.—Vertical pug-mill.

further description here. Mixers of other patterns also serve a useful purpose as automatic feeders for

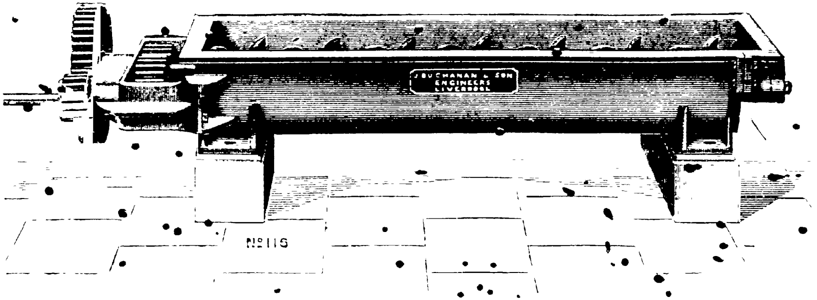

FIG. 58.—Open mixer.

the regular delivery of material to the grinding mills.

### MACHINERY FOR SHAPING CLAYS

The material having been obtained in a suitable form, by means of the preparative machinery already described, it is next necessary to give it the desired shape in order to convert it into bricks. For this purpose six types of machines are available, according to the consistency of the material used.

*Machines imitating Hand Moulding* are employed in some districts in order to avoid the difficulties which arise owing to the scarcity of skilled moulders. In these machines the prepared clay paste is compressed into moulds similar to those used for hand-moulding, but arranged in series of four or six, and usually provided with a bottom board. These machines have only met with a limited success, though with suitable clays very satisfactory bricks can be made. The "Monarch," made by Knott & Co., Ltd., Hull, and the "Anglo-American" machine by Thos. C. Fawcett, Ltd., Leeds (Fig. 59), are the best known machines of this type.

*Wire-cutting Machines* are used in connection with pug-mills of the horizontal type, and to a small extent on vertical ones. They require a plastic material which is forced out of the pug-mill in the form of a compact band about 9¾ in. by 4¾ in. in width and thickness (the exact size depending on the shrinkage of the clay). This band is then cut crosswise by means of wires so as to form bricks.

The band is usually produced by fixing a specially shaped die or "mouthpiece" (Figs. 56 and 60) to the

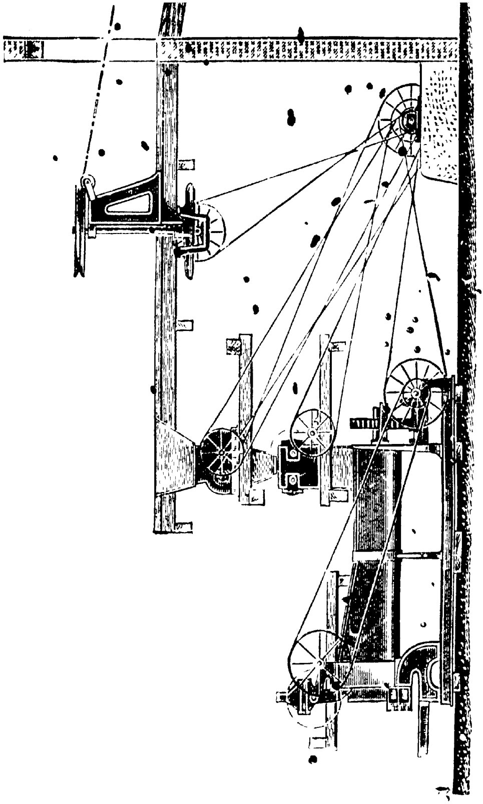

FIG. 59.—"Anglo-American" brick machine.

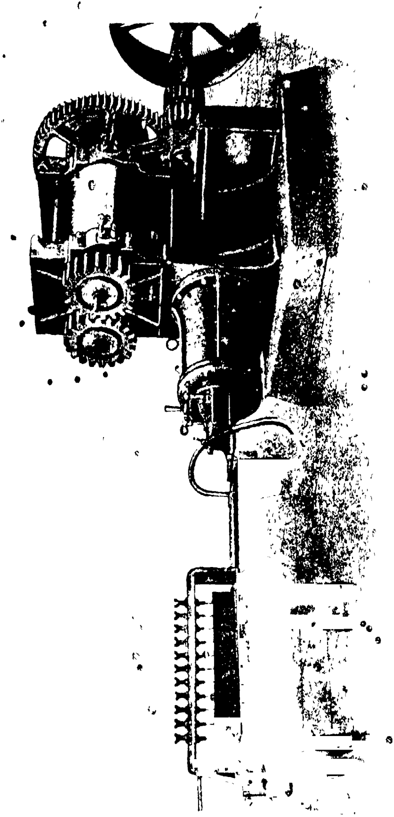

FIG. 60.—Brick machine for plastic clay.

exit of a powerful pug-mill, so that as the clay passes out of this it is of the desired shape. When a convenient length has been extruded the band is cut by a stretched wire in a movable frame and is pushed on to the cutting table. This latter (of which there are numerous patterns) consists essentially of a table and a frame with a number of stretched wires, placed a suitable distance apart (Fig. 61). These wires may then be pushed sideways or downwards through the clay, by means of suitable hand-driven mechanism, or, what is more usual in this country, the frame and wires remain fixed and the clay is pushed against the wires, and so is cut into a number of bricks. These bricks are placed on a pallet-board (p. 85) or waggon, and are taken away to be dried, on a hack ground or (more usually) in a drying-shed heated by steam or fires (Fig. 36), or in a tunnel-dryer (Fig. 73).

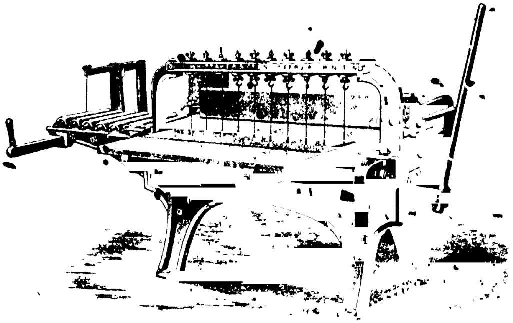

Fig. 61.—Cutting Table.

The process is extremely simple, and large quantities of bricks can be made by this process. Considerable skill is, however, needed in the construction of the pug-mill and mouthpiece, or the power required will be excessive and the clay band will be defective in shape and texture.

Wire-cut bricks cannot have any "frog" or other indent in their larger faces, but where these are not required this method produces an excellent quality of brick at a cheap rate, the wire-cut bricks being smooth and perfect in form, provided the clay be not only perfectly plastic, but *perfectly uniform* and free from adventitious particles. If, however, the plastic clay contains gravelly particles, or be of such a quality that it is necessary to mix it with ashes or "breeze," then the section made by the passage of the wire drags out some of these solid particles, and the cut faces of the bricks are rough and uneven. In such cases it may be better to use one of the machines described in the later sections of this chapter.

Instead of attaching the mouthpiece to a pug-mill, it is sometimes advantageous to connect it to a pair of *Expression Rolls*, consisting of two horizontal rolls placed one above the other, as in a domestic mangle for wringing clothes. The clay paste is fed into a hopper at one side of these rolls, and is delivered through the die at the other side in the form of a band of the desired section. This arrangement is particularly useful for clays which laminate when the mouthpiece is attached to the pug-mill (Fig. 62).

In making bricks by the wire-cut process it is usual to mount the crushing rolls and pug-mill on to a single framework, and to speak of the whole as the

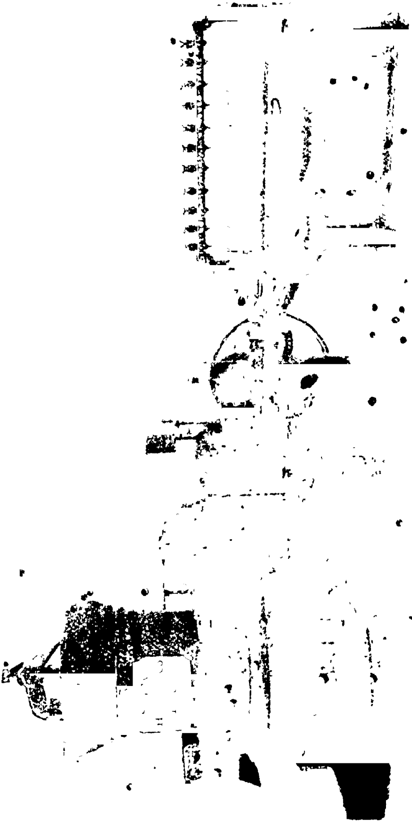

FIG. 62.—Expression rolls brick machine (Murray type)

brickmaking machine. According as one or more pairs of rolls are added, such machines are sometimes termed "two process," "three process," etc., machines. Fig. 60 shows a machine of the former type.

*The Stiff-Plastic Process* is a term used by a number of manufacturers to indicate the production of bricks by compressing a stiff-plastic clay mass into moulds by powerful mechanism in order to give it the desired shape. This method of working permits the material to be used in a much stiffer condition than when "hand-made" or "wire-cut" bricks are being produced, and so effects a considerable saving in the time required for drying the bricks.

A considerable number of different patterns of machines designed for this purpose are in use, but in each of them a "clot" is first formed by some simple process—usually by making a powerful pug-mill deliver into a box mould placed at its exit, and rotating as soon as the mould is filled. The clot is next passed into a press and is compressed accurately to the desired shape.

The clot-moulds may be arranged in a horizontal table with a vertical pug-mill delivering on to its upper face (Fig. 63), or the moulds may be arranged on the circumference of a drum, as in the machines made by T. C. Fawcett, Ltd. (Fig. 72).

The bricks made by this process combine the accuracy of form possessed by those made from dry dust, with the advantages of texture possessed by those produced from a plastic paste. They can, however, only be made from comparatively dry materials such as shales and the drier brick-earths.

For these materials this process is probably the best yet devised where facing bricks of a plastic character are required.

About 12,000 bricks can be made per day by each machine. For further details see Chap. X.

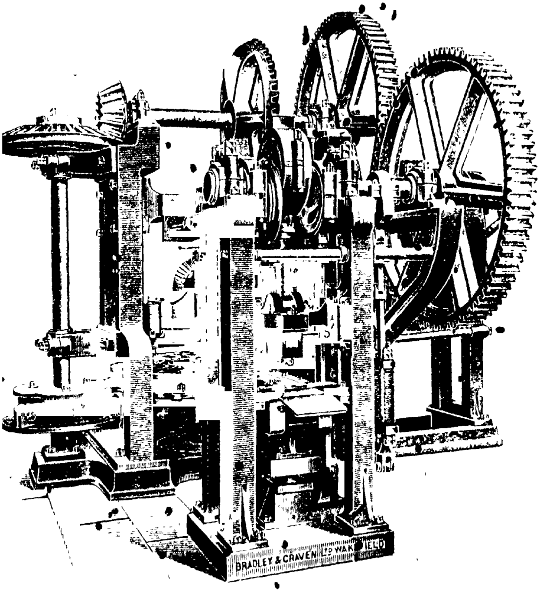

Fig. 63.—Stiff-plastic brick machine (with table).

*The Semi-Dry Process* consists, as its name implies, in the utilization of material in a semi-dry condition, *i.e.* in the form of a slightly moist powder. It is chiefly used in the production of bricks from shales and rock clays. It has the advantage over the processes previously mentioned of permitting the bricks to be taken direct to the kiln—without drying—but is less popular than the stiff-plastic process in many districts, because bricks made from a plastic, or partially plastic material have a number of technical advantages.

This process has been extensively used at Fletton, near Peterborough, and elsewhere with very satisfactory results. A brief account of it will be found in Chap. IX., but there are several other types of machines used in other districts for a description of which a larger treatise such as "Modern Brickmaking" should be consulted. It is claimed to be the cheapest process yet invented for the production of very large quantities of bricks from shales and similar materials.

*The Dry-Dust Process* is seldom used for brickmaking, as it requires the material to be dried before use and is extremely wasteful in power. In principle it is precisly similar to the "semi-dry" process just described. In the manufacture of wall tiles and tesseræ this process is extensively employed.

One of the disadvantages or difficulties of making perfectly sound and solid bricks from dry or nearly dry clay, however finely pulverized, is that the air lodged in the interstices of the clay dust is sometimes not easily and completely expelled by a single compression, but lodges in one or more irregular cavities into which it has collected, and so leaves the brick hollow. One of the main objects of all machinery makers is to obviate this evil, which is accomplished by relieving each brick from pressure and again applying it, so as gradually to force out the air, and finally consolidate the brick, and that to an extent that a single pressure, though greater, and hence exerting a greater strain on the machine, might not accomplish.

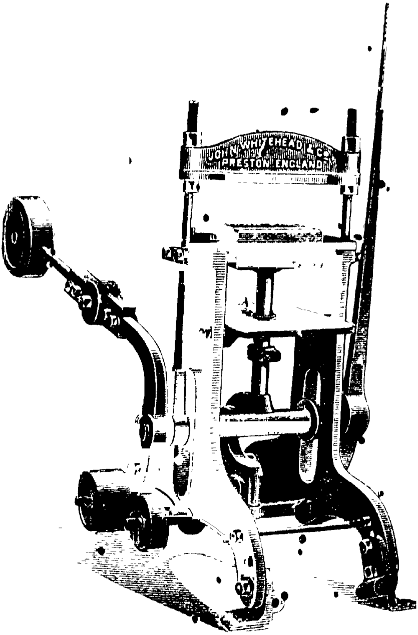

FIG. 64.—Portable lever press.

In this way two or three distinct pressures are given to each brick. If the clay is of such a character that the whole of the air cannot be expelled or the dust sufficiently condensed to make a perfect brick by two pressures, then a third is given. With most clays two pressures will be found sufficient.

*Repressing* is necessary when great accuracy of form is desired. In the case of hand-made bricks, the partially dried articles are pressed in a portable lever press of the type shown in Fig. 64, which is taken

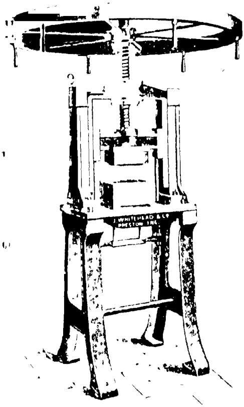

FIG. 65.—Screw press.

to the bricks, or they may be brought to a screw press of the type shown in Fig. 65. If desired, this latter type of press may be power-driven. Bricks made by the wire-cut process (p. 184) are usually repressed in machines of this type or in the presses forming part of those shown in Figs. 63 and 72.

Much difference of opinion exists as to the value of repressing; in some cases the strength and durability of the material appear to be impaired by this treatment.

## ENGINES.

In country districts and especially in the Colonies portable engines (Fig. 66) are the best and cheapest in every way, but for a permanent establishment in a more accessible situation, engines upon fixed bed-plates or foundations are to be preferred.

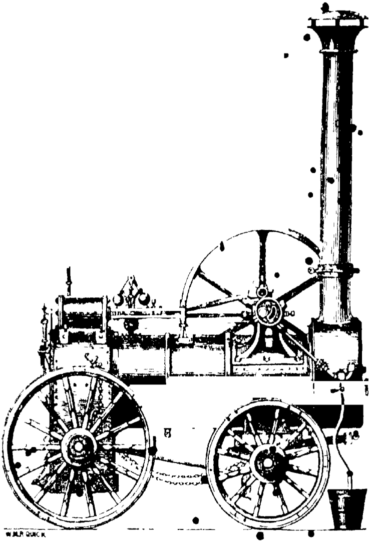

FIG. 66.—Portable Engine.

The type shown in (Fig. 67) is used in a large

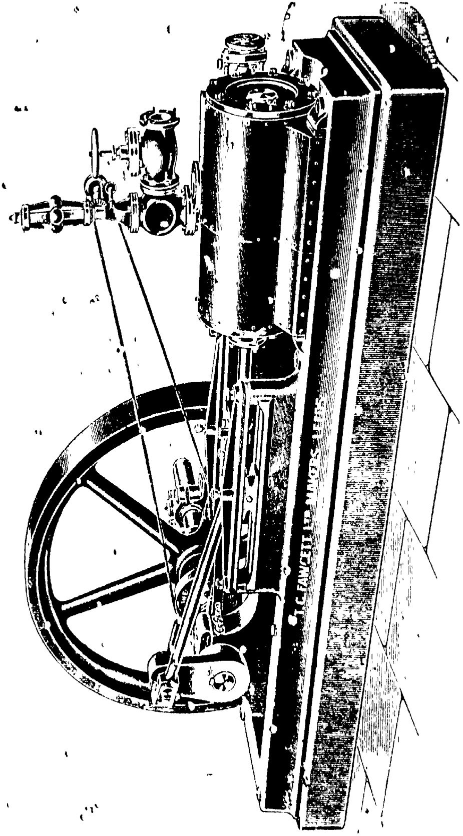
T. C. FAWCETT LD MAKERS LEEDS

FIG. 67.—Stationary engine for brick-works.

number of works. The fly-wheel is fitted for driving by belt or ropes as desired.

As the amount of power may vary greatly from time to time, it is important that the engine should be sufficient for all likely demands upon it; for a stone in a grinding mill to stop the engine is sometimes disastrous.

Suitable engines of either type are made by the manufacturers of brickmaking machinery.

# CHAPTER IX

## THE MANUFACTURE OF BRICKS NEAR PETERBOROUGH AND ACCRINGTON

So important have been the results of the application of the semi-dry method of brick-making within recent years that Peterborough has become a prominent centre for "semi-dry" or "semi-plastic" bricks; about 95 per cent. of the machinery in this district being of this type, and it is therefore, desirable that this process should be described in so far as it is used in the Fletton district.

### PETERBOROUGH DISTRICT.

The material employed in the neighbourhood of Peterborough consists of what is known geologically as the Oxford Clay, and is largely of a shaley character and of a curiously irregular composition. For this reason it is necessary to mix the materials from a number of different strata together in order to obtain good results. To do this by hand is both difficult and costly, so that the London Brick Co. Ltd—one of the most successful firms in this district—have long employed steam navvies for the excavation of their material. The navvy takes a cut whose depth is the full swing of the bucket, and so a material of sufficiently regular composition is obtained.

The material is sufficiently free from moisture to be worked by the semi-dry process, and this method of manufacture is seen to its greatest advantage at Fletton. As already mentioned in Chap. VIII. p. 191, it consists in grinding the clay to a powder and compressing this in powerful presses so as to form bricks, which can be taken direct to the kiln without being previously dried.

The callow or overburden is first removed and discarded, and the material to be used is excavated by a steam navvy; it is tipped from the navvy bucket into a waggon, and is conveyed by a tramway operated on the endless haulage system to the mills. Here the contents of the waggon are emptied on to a chute and conveyed to edge-runner mills with revolving pans. The crushed material is conveyed automatically to a "piano-wire" screen, and the fine powder is received on a hopper or floor whence it travels to the presses. It must contain sufficient moisture to "bind" properly, but not enough to become sticky. If water is added care must be taken to pass the material through a suitable mixer.

The presses employed by the London Brick Co., Ltd., are of the type shown in Fig. 68. The material is fed into the machine by means of a sliding mould, the amount so supplied being capable of instantaneous adjustment. It is then subjected to two pressures—with automatic provision for the escape of air between each—and is then passed into a second mould. Here it is again pressed twice, so that the complete brick has received in all four pressures, each of about eighty tons. Each machine will produce about 6000 bricks per day.

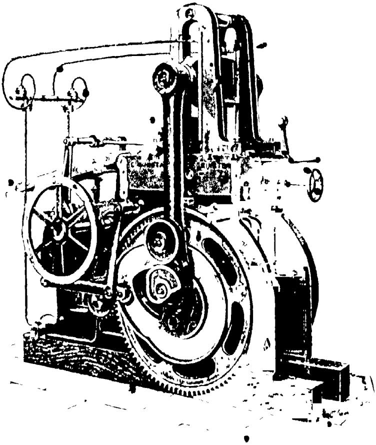

FIG. 68.—Press for semi-dry process.

The general arrangement of the plant is shown in Fig. 69.

The bricks are taken direct from the press to a continuous kiln of special design, but operated largely upon the Hoffman principle (p. 50), with additional flues for the effective drying and warming of the newly set bricks. As the Fletton shale contains oil, only very little fuel is needed, about two cwts. being sufficient, and much less than this on some occasions.

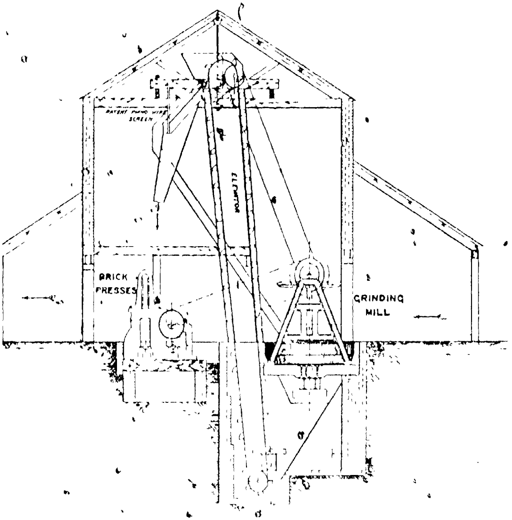

FIG. 69.—Whittaker's arrangement of plant for semi-dry bricks.

Several firms have attempted to make bricks in the same district by a similar process, but have failed; (*a*) because of the irregularities in the material, (*b*) through insufficient mixing, (*c*) through too few or too weak pressures, and (*d*) unsatisfactory kiln management. The Oxford Clay is, in fact, a difficult material to work, and needs exceptional skill if it is to be used profitably on a large scale.

### ACCRINGTON BRICKS.

With regard to the Accrington material, all the bricks in this district up to a few years ago were made semi-dry, or semi-plastic, and just outside the Accrington area the whole of the bricks are made semi-dry at the present time. The demands of architects for stiff-plastic bricks have, however, resulted

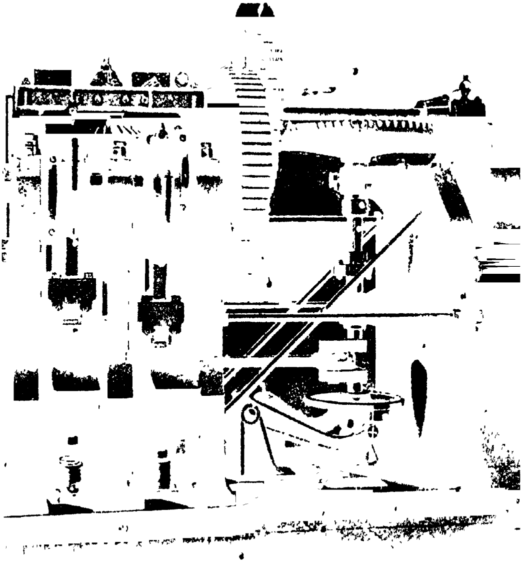

FIG. 70.—"New Era" stiff plastic brick machine.

in a change of process, and now many of the best bricks at Accrington are manufactured by the stiff-plastic method (Chap X.), the chief machines used being Whittaker's "New Era" machine (Fig. 70), Fawcett's "Stiff-plastic" machine (Fig. 72), and Bradley and Craven's "Stiff-plastic" machine (Fig. 63).

# CHAPTER X

## THE MANUFACTURE OF BRICKS IN THE MIDLANDS AND NORTHERN COUNTIES

THE districts in which the stiff-plastic process is used extend over most of the Midlands and North of England, and over a large part of Wales. The materials to which it is applied differ greatly, and compel slight variations in the method of working, but that largely used in South Yorkshire may be regarded as typical (the use of this process for the best bricks in Lancashire is mentioned on p. 201 under "Accrington bricks").

The material is dug by hand or excavated by a navvy, and is placed in small waggons running on rails. If the material is very hard, blasting may be necessary.

The waggons are hauled from the clay pit or quarry up an inclined plane to the mill house, by endless haulage or by a single rope or chain. The latter method is only used for small outputs or in specially difficult positions. The contents of the waggons (Fig. 71) are emptied by means of a tipping-frame into the feeder or on to a feeding-floor, from whence the material is supplied, either automatically or by spade labour, to edge-runner mills with perforated revolving pans (p. 175). The crushed material

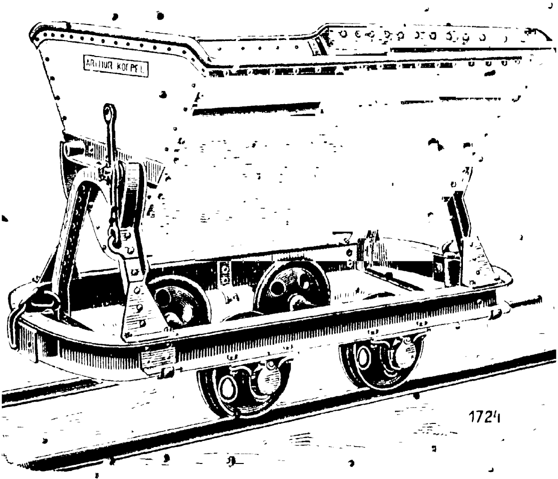

FIG. 71.—Tipping waggon for clay transport.

is screened, and the fine powder is passed into a suitable pug-mill which forms part of the brick-making machine. Here it is mixed with water, and formed into a stiff, plastic paste. If desired, it may first be treated in another open mixer, though this is seldom essential.

The stiff paste is carried forward by the action of the knives of the pug-mill, and the clot mould on the horizontal table (Fig. 63), or on the revolving drum (Fig. 72) is filled. As the table or drum revolves, a fresh mould is brought to the orifice of the pug-mill, and this action is continued until one of the filled clot-moulds is emptied by an appropriate device which operates automatically. The clot is next pushed or lifted into the brick-press, where it receives its final shape. Sometimes it is repressed if specially dense or accurately shaped bricks are required (p. 194).

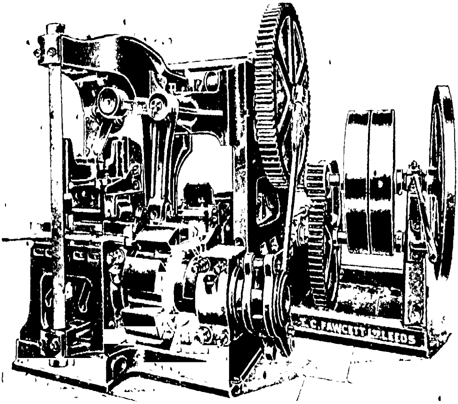

FIG. 72.—Stiff plastic brick machine (with drum).

The bricks are now taken to a drying shed, where they are laid on floors heated by steam or fires (Fig. 36), or to a tunnel dryer (Figs. 73 and 74). In the latter, the bricks are stacked on cars and pass into one end of a tunnel; they are there heated progressively as they pass forward, the dry bricks passing out at the other end. The air used in drying may travel in the same direction as the bricks ("direct" system), or in a contrary direction ("inverse" system). It is heated by steam, fires, or waste kiln gases. Tunnel dryers are more rapid than sheds, but are more costly to instal, and require more skilled attention.*

When quite dry the bricks are burned in a continuous kiln. In a few cases it is possible to take the bricks direct from the press to the kiln, but the danger of doing this lies in the fact that if heated too rapidly many of them will be spoiled.

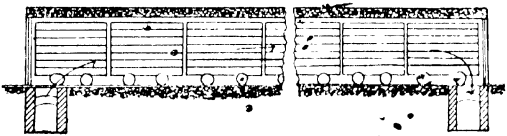

FIG. 73.—Vertical section of tunnel dryer.

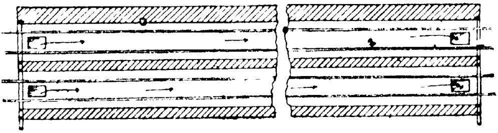

FIG. 74.—Plan of tunnel dryer.

Usually the bricks are allowed three to five days to reach a red heat, two more days to reach the finishing temperature, and five days to cool. For continuous kilns of ordinary dimensions this corresponds to an output of one chamber per working day. About 3 to 5 cwt. of fuel are required for each

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* The subject of tunnel dryers is too complex for inclusion in a rudimentary treatise, especially as "Brick Drying" by A. E. Brown deals very completely with the construction of all the best types.

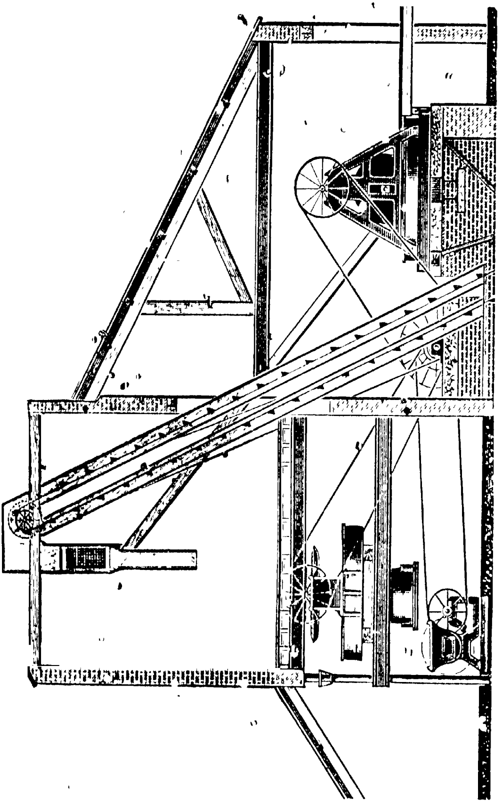


FIG. 75.—Fawcett's arrangement for stiff plastic brickmaking.

thousand bricks, but this depends to some extent on the construction of the kiln. Seger cones are useful for ascertaining the final temperature reached.

# CHAPTER XI.

## LIME-SAND AND CLINKER BRICKS

WHERE clay is scarce or unsuitable, but sand or siliceous rock is obtainable, bricks may be made of these materials by the use of lime as a binding agent. In a somewhat similar manner, bricks may be made from the clinker obtained from refuse destructors.

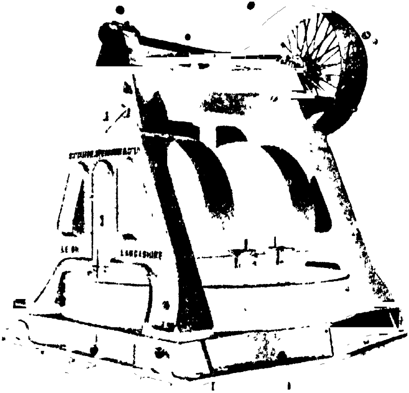


FIG. 76.—Edge-runner mill for grinding silica rocks, etc.

The material must be sufficiently fine to pass through a No. 8 screen, and if coarser than this must be ground in an edge-runner mill (Figs. 53, 55, and 76).

Quicklime is ground with some sand to such a fineness that it will pass through a No. 50 sieve, a ball-mill being the most suitable machine for this purpose. The ground materials are now mixed so that the mixture contains 6 to 10 per cent. of lime, the correct proportion for any given material being ascertained by tests.

During the mixing water is added, and the wet material is subjected to a "boiling process" in the mixer. It then falls into silos, where it is stored for one to three days in order that the lime may be properly slaked and the moisture uniformly distributed. Unless this is done the bricks will not be sound.

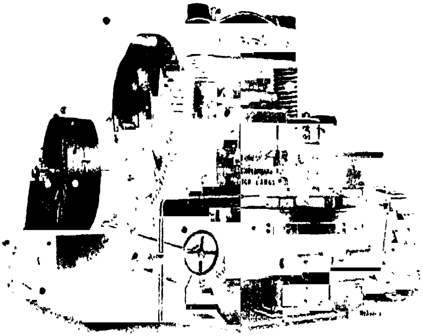


FIG. 77. -Press for lime-sand bricks.

The stored material is next taken to a powerful press (Fig. 77), where it is compressed into bricks under an enormous pressure (100 to 150 tons) so that the bricks will stand fairly rough treatment.

The bricks are next stacked on waggons and wheeled into a "hardening chamber," where they are subjected to the action of steam at 125 lbs. per sq. in. for 8 to 10 hours. After withdrawal they are fit for immediate use, and improve on storage.

The hardening chamber (Fig. 78) consists of a steel cylinder 35 to 70 ft. in length and 6 ft. internal diameter, one end being removable and, when in use, is held in place by strong bolts. It will be noticed that these bricks are not burned in kilns, but are simply steamed.

FIG. 78.—Hardening chamber for lime-sand bricks.

Lime-sand bricks are white, but clinker bricks resemble the blue bricks of Staffordshire. Both kinds require the use of appliances specially designed for the purpose. Those illustrated are supplied by Messrs. Sutcliffe, Speakman & Co., Ltd., Leigh, Lancs., who have erected some of the most successful plants of this kind in the country. So far as clinker bricks are concerned, this firm claims that only by using their process (outlined above) and their patent mixer can these bricks be satisfactorily made.

# CHAPTER XII

## TILE MANUFACTURE: GENERAL PRINCIPLES

TILES are used for a variety of purposes, and may be divided into two main groups—

(*a*) Unglazed tiles made of natural clays;
(*b*) Glazed tiles made of a mixture of fine clays and other materials forming an earthenware or porcelain body.

The second group is a branch of the pottery trade which has no connection with the manufacture of bricks, and is therefore omitted from the present volume.

*Glazed roofing tiles* are comparatively new to this country, though much used in Spain, India, and some other countries. Their manufacture may, therefore, be regarded as outside the scope of the present rudimentary treatise.

The first group consists of tiles which are manufactured in a similar manner to bricks, the principal differences arising from the thinness of the ware, which requires the clay to be finer and stronger, and renders it necessary to conduct the whole of the processes more carefully than in making bricks.

In this group of tiles are four classes, viz. paving tiles, encaustic tiles or tesseræ, roofing tiles, and drain tiles.

*Paving tiles* may be considered simply as thin bricks, and require no special notice.

*Encaustic tiles* are chiefly used for interiors (see p. 249).

*Roofing tiles* are of three kinds: *pantiles*, which are of a curved shape; *plain tiles*, which are flat; and *interlocking tiles*, which are often made of ornamental shapes, so as to form elegant patterns when laid on a roof.

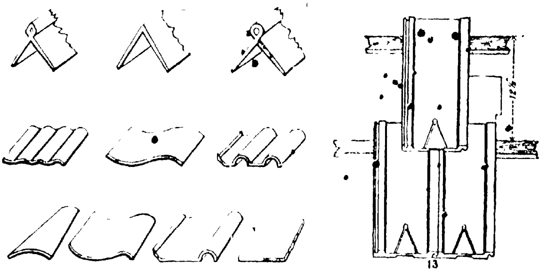


Fig. 79.—Roofing tiles.

Pantiles, when hand made, are moulded flat, and afterwards bent into their required form on a mould. Plain tiles were formerly made with holes in them for the reception of the tile-pins, by which they were hung on the laths; but the common method is now to turn down a couple of nibs at the head of the tile, which answer the same purpose. Interlocking tiles are moulded by hand in specially designed moulds, or, more usually, they are made in a wire-cutting machine (p. 184) or in a powerful mechanical press.

True *Spanish tiles* are of semi circular section, and sufficiently conical for the lower end of one tile to fit in the upper end of the tile below and thus provide a suitable overlap. Such a tile is shown in the bottom left-hand corner of Fig. 79. The tapered form secures beautiful effects in use, but is troublesome to make, with the result that tiles of an S-shaped section (Fig. 79) are generally preferred in this country.

*Interlocking tiles* are usually rectangular in outline, with the surfaces corrugated, so arranged that the corrugations of one tile fit or lock into those of another, the right-hand tongue or groove forming the cover, and the left-hand groove or tongue the under portion of the joint. Similar locks are formed at the top and bottom of some tiles, but in others a simple overlap is regarded as sufficient (see Somerset Trading Co.'s patent at right of Fig. 79).

Interlocking tiles are a product of the introduction of shaping machinery into clay-working, and are chiefly made by expression and wire-cutting in a similar manner to wire-cut bricks (p. 184), or by pressing slabs of clay in presses employing plaster moulds. A few interlocking tiles are made by hand, but this seldom yields tiles with tongues and grooves of sufficient accuracy and shape. Interlocking tiles are usually less liable to twist than plain or pantiles; they form a more weatherproof roof, which can be constructed for a lower cost than one of other tiles.

The manufacture of interlocking tiles is described in such detail in "The Manufacture of Roofing Tiles" by E. L. Raes, that the reader requiring further information should consult that volume.

*Hip and Valley tiles* are used where two portions of a roof meet at an angle. If the angle is towards the inside of the building—forming a kind of gutter, valley tiles are required; for an external projection or ridge, hip tiles are used.

The angle varies with the architectural design, and for this reason most hip and valley tiles must be made to order, either in special moulds or by cutting tiles already made when the latter are in a leather-hard condition.

*Ridge and Eave tiles* must be made specially—usually in plaster moulds, though perfectly plain ridge tiles (three of which are shown at the top of Fig. 79) may be made by expression from a brick machine as in making wire-cut bricks (p. 184).

More complex designs may be produced by this process, followed by cutting out by hand the portions of the tile not required.

*Finials* are needed at the end of the ridge and at the top of a gable or tower. They must be modelled specially or made by hand in plaster moulds.

*Draining tiles or pipes* belong to the coarsest class ot earthenware. They are of various shapes, and are made in various ways. Some are moulded flat, and afterwards bent round a wooden core to the proper shape. Others are made at once of a curved form, by forcing the clay through a mould by mechanical means. Pipe-making machines have now almost universally superseded manual labour in this manufacture, and many machines of various degrees of merit have been patented (see Chap. XVI.).

*Machine-made tiles* are generally produced by expression in a manner precisely similar to "wire-cut bricks," so that no description of this method of manufacture is necessary in a rudimentary treatise. The reader who wishes for further details should consult "Roofing Tile Manufacture," by E. L. Raes (see Appendix).

The same remark applies to the production of interlocking tiles, which are made in powerful mechanical presses.

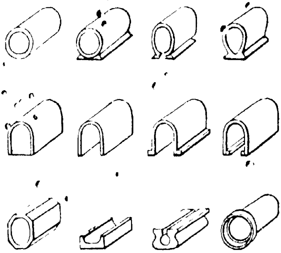


FIG. 80.—Drain pipes and tiles.

It is customary to burn bricks and tiles together, the former occupying the lower part of the kiln. In some districts, however, the demand for tiles is sufficiently great to justify the erection of special kilns—usually of a circular downdraught type.

## PRESSING IN PLASTER MOULDS.

In making tiles of special shapes in plaster moulds the clay paste must be quite soft, and should be shaped into a clot or roll. The plaster mould is placed on a bench similar to that shown in Fig. 102, and is dusted over with a bag filled with dry clay dust so as to produce a thin even coating of dust on the plaster. The roll or clot of clay is then thrown forcibly on to the plaster, and is kneaded to shape with the hands until the mould is properly filled. Any superfluous clay is cut off with a sling (Fig. 85) or bow and wire (Fig. 102). The mould, with its contents, is then placed aside until the clay has shrunk sufficiently for it to be turned out on to a pallet on inverting the mould.

For finials and complex pieces of work the mould must be made in several pieces, each of which are filled separately and then joined together. The various parts of the mould are held in position by means of an iron band, by cord, or by an outer mould or case. The seams or joints in the clay are then made good by pressing and working with the fingers, and by the aid of small tools, the inside of the article being then finished by hand. After the clay has shrunk away from the plaster, the mould with its contents is inverted on to a board of suitable size, and the mould carefully removed piece by piece.

Articles made from new plaster moulds should require little or no finishing, but when the moulds become worn it is necessary to make good any defects in the surface of the article by careful modelling.

## CHAPTER XIII.

### THE MANUFACTURE OF PANTILES

PANTILES are curved in so peculiar a manner that they are seldom made by machinery, though with care they can be successfully produced in the same manner as wire-cut bricks (p. 184). Owing to the compressive treatment or "thwacking" to which the hand-made tiles are subjected they are generally regarded as superior in quality. The term "pantile" is used for all hollowed tiles, but as the shapes most commonly employed are the first three in the bottom row of Fig. 79, the term is usually restricted to these. Of these three illustrations, the first is also termed a Spanish tile (p. 212), the second an S-tile, and the third an interlocking Spanish tile.

The manufacture of *hand-made pantiles* has been greatly improved in recent years by the substitution of improved methods of preparing the clay, the old type of pug-mill driven by a horse (Fig. 13) being usually replaced by a much more powerful machine driven by an engine (Figs. 56 and 57).

This change has been rendered necessary (1) by the scarcity of the material formerly used; that now employed requiring a more thorough pugging if it is to prove satisfactory; and (2) by the greatly increased competition which, with the increased cost of labour, has compelled tile-makers to reduce the costs of manufacture as much as possible, and to eliminate human labour whenever practicable.

In purely agricultural districts, where labour is more plentiful and fuel scarce, the earlier appliances may still be used with advantage, as they may be more readily repaired by the village smith or carpenter. Hence, in the following pages, they are described in greater detail, as the more modern ones—being purchased ready for use—are essentially the same in general principle though more complex in structure and more powerful in action.

*Buildings and Plant.*—These may be of a simple nature where the clay does not require to be crushed before use. If a hard material is used, or the plant is driven by an engine, a more substantial set of buildings will be required. In the simplest method of tile-making, the chief building is the moulding shed. This is a structure about 7 yards wide, its length depending on the number of moulding-tables, the area allotted to each table being about 7 yards in length by 4 yards in breadth.

The moulding-tables are placed against one side of the shed, and the remainder of the area is occupied by the *blocks* or drying-shelves; every shelf being formed with three 11-in. planks placed edge to edge, and separated from each other by bricks placed edgewise at the end of the planks, as well as at intermediate points, each block containing about 14 shelves, and thus measuring 12 ft. long by 2 ft. 8 in. wide, and about 7 ft. high. A passage way, 3 ft. wide, is left round the blocks, to give free access to every part of them.

These details will be understood by reference to

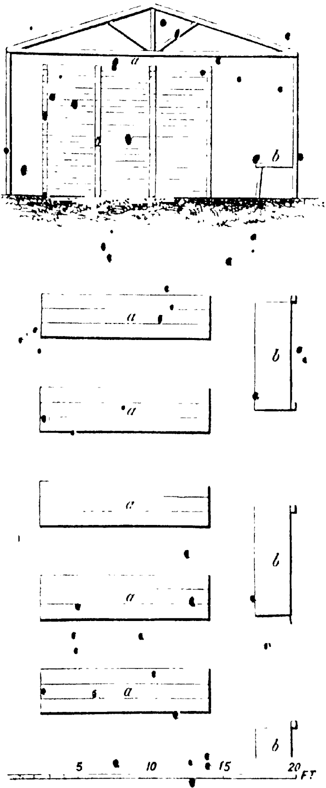


FIG. 81.—Tile-shed (section and plan)

Fig. 81, in which a typical shed is shown in plan and section. In this illustration, *a, a, a,* are a series of shelves, on which the tiles are placed to dry.

The moulding-tables *b, b, b,* are placed at one side.

*Pug-mill.*—The horse-driven pug-mill used in pantile-making for pugging the clay, differs considerably from the apparently similar one used in brick-making. The tub, instead of being conical, is made to taper at both ends (Fig. 82), and the ejectment hole is at the bottom instead of in the front, as in the brick pug-mill.

The knives (Fig. 83), also, are made in a superior manner, being stronger and better fitting. The pug-mill is provided with forcing knives at top and bottom. These forcing knives have no cross knives attached to them. The pug-mill is generally placed under cover.

As previously mentioned, a far more effective pugging can be given by a mechanically driven pug-mill (Figs. 56 and 57).

If the clay requires crushing, it must be passed through rollers (Fig. 59) before it enters the pug-mill.

*The moulding-table* for pantiles is shown in Fig. 84. It is furnished with a *trug* or trough (*c*) in which the moulder dips his hands when moulding, and with a *block and stock board* (*b*) on which the tile mould is placed in the operation of moulding, and with moulder's sand (*d*). The strippings (*e*) are placed in the far corner, and a hole (*f*) in the table allows sweepings to drop through.

The mould is placed on four pegs *g, g, g,* one at each corner of the block and stock board; and the

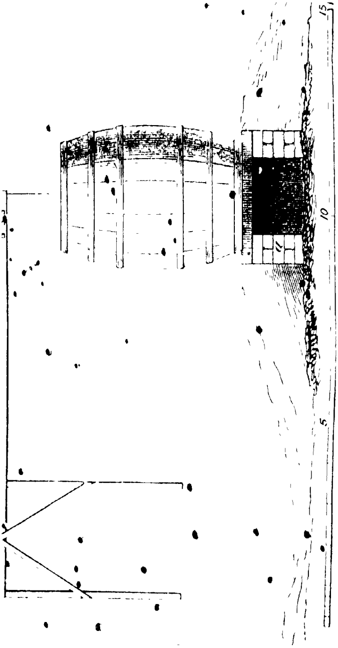


FIG. 82.—Horse-driven pug-mill for tile-making.

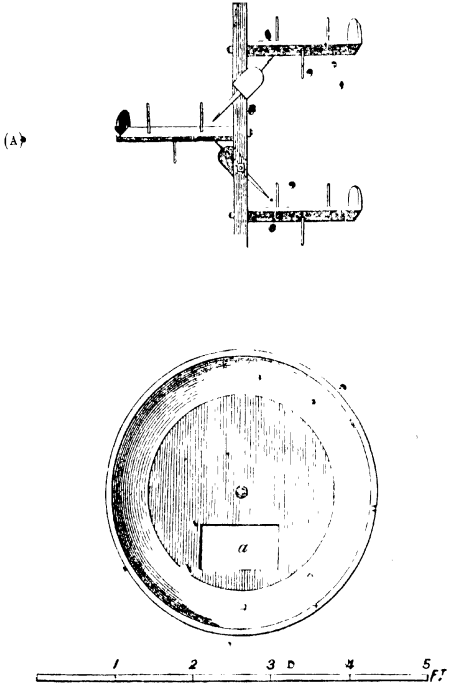


FIG. 83.—(A) Knives in pug-mill. (B) Cross-section of pug-mill showing ejectment hole (*a*).

distance to which they are driven below the top of the stock board, determines the thickness of the tile.

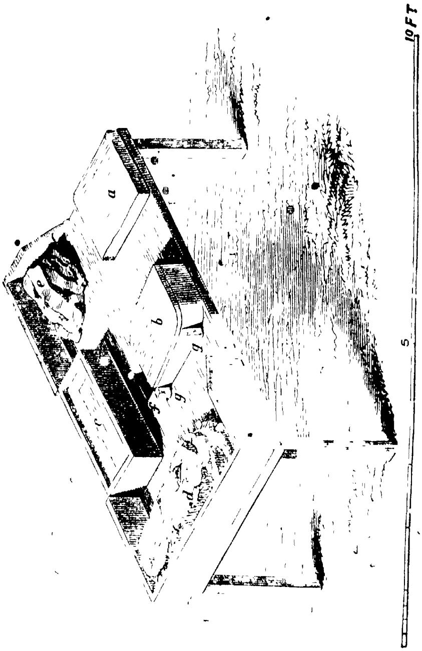


FIG. 84.—Moulding-table for pantiles.

*The Sling* (Fig. 85) is simply a piece of thin wire with two handles, used for cutting the clay.

*The Block and Stock board* is shown in Fig. 86. The two form one piece, which rests on the moulding-table, and is firmly keyed to it by means of a tenon

Fig. 85.

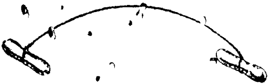


Fig. 86.

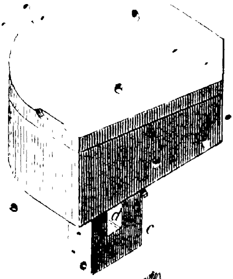


Fig. 87.

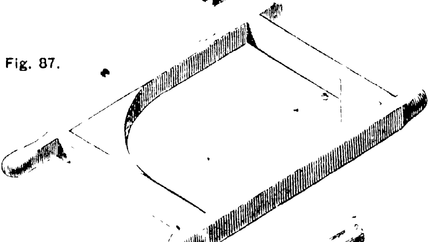


Fig. 88

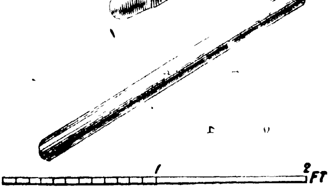


FIG. 85.—The sling.
FIG. 86.—The block and stock board.
  *c.* A tenon, which drops into a mortice in the table
  *d.* A mortice in *c*, by which the block and stock board is keyed tightly to the table.
FIG. 87.—The pantile mould.
FIG. 88.—The roll

on the under side of the block passing through a mortice in the table. Four pegs, driven into the table at the corners of the block and stock-board, serve as a support for the mould, and regulate the thickness of the tile, ⅝ in. being the thickness of a pantile.

Fig. 89

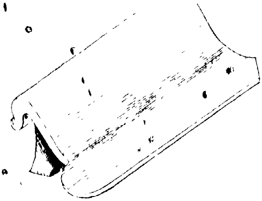


Fig. 90.

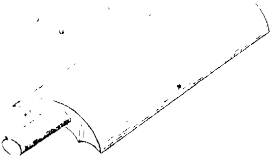


Fig. 89.—The washing-off frame.
Fig. 90.—The splayer.

*The Tile Mould* is shown in Fig. 87. It is made of wood, and requires no further description.

*The Roll* (Fig. 88) is merely a round roller of a convenient size, as shown by the scale, and is used for striking a smooth surface to the tile.

*The Splayer* (Fig. 90) is an instrument on which the tile is removed from the washing-off frame to the block.

*The Washing-off Table* (Fig. 91) is a stand with a water trough and a frame called the *Washing off Frame*, (see Fig. 89), on which when moulded, the tile

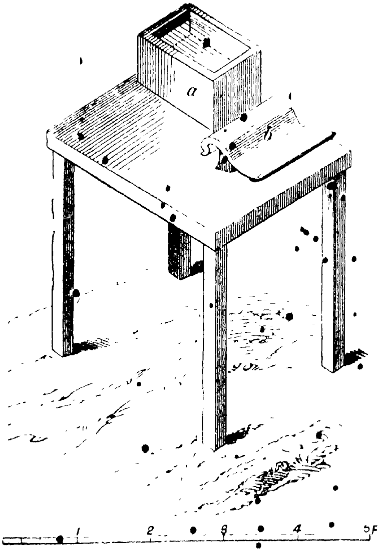


FIG. 91.—The washing-off table.
*a*. The washing-off trug. *b*. The washing-off frame.

is *washed* into a curved form. The washing-off table is placed at the left-hand end of the pantile table, and near the block.

*The Thwacking Frame* (Fig. 92) is a frame on which the tile, when half dry, is *thwacked* or beaten with a *thwacker* (Fig. 95), to correct any warping which may have taken place whilst drying in the block.

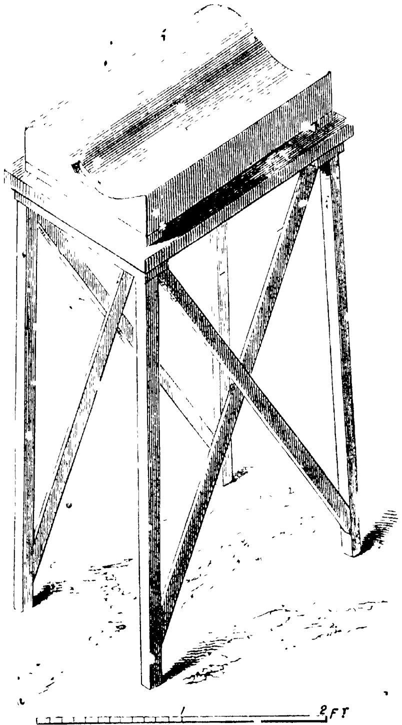


FIG. 92.—The thwacking frame placed on the thwacking stool.

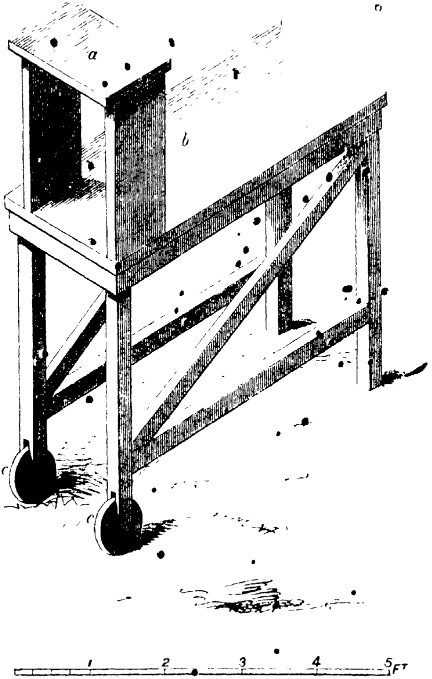


FIG. 93.—The thwacking horse, on which the thwacking frame is placed for thwacking those tiles at the top of the blocks

*a*. The table on which the thwacking frame is placed.

*b*. The place where the thwacker stands.

*c*, *c*, Two wheels to facilitate the moving of the horse from place to place when required

When thwacking those tiles taken from the bottom of the block, the thwacking frame is placed upon the *Thwacking Stool* (Fig. 92), but when the tiles to be thwacked are at the top of the block, the thwacking frame is placed upon the *Thwacking Horse* (Fig. 93), which brings it conveniently to their level.

The *Thwacking Knife* (Fig. 94) is used for trimming the wing of the pantile immediately after thwacking. This is simply an iron blade, with a piece cut out exactly to the intended profile of the wing of the pantile, which is trimmed with it immediately after thwacking.

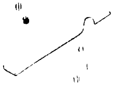


FIG. 94.—The thwacking knife.

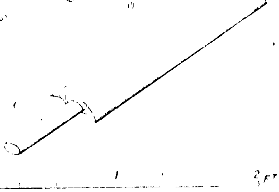
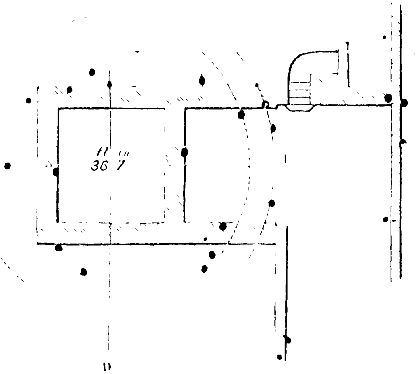


FIG. 95.—The thwacker.

*The Tile Kiln* may be the same as that used for bricks, if the latter are burned in a downdraught kiln or in a chamber kiln of a modern type on the continuous principle. The latter can only be used where the demand for bricks and tiles is very large, so that in practice single kilns are generally used.

Where simplicity of erection is more important than a saving in fuel or a uniform colour in the goods an updraught kiln of the pattern shown in Figs. 96 to 101 may be erected, though the most



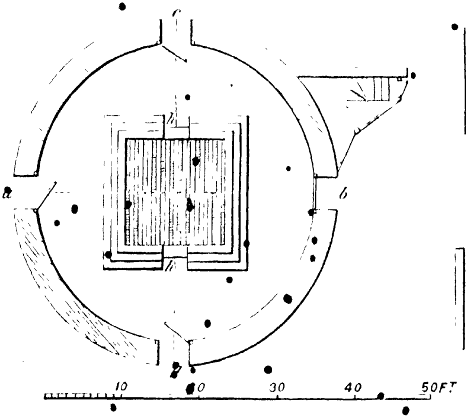


FIG. 96.—Plan of the basement, showing entrance to vaults.
FIG. 97.—Plan of the kiln, taken through the body.
*h*, *h*, The hatchways.

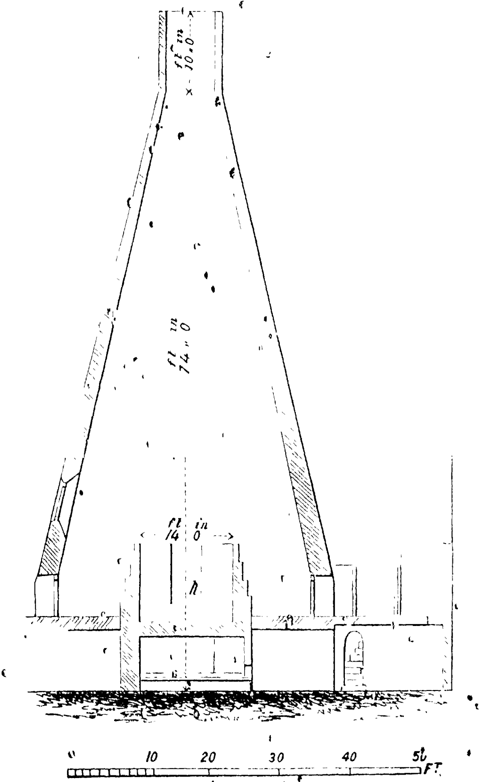


FIG. 98.—Section through the centre of the kiln, in the direction of the line *ab*, Fig. 97.

This and the following engraving are not quite accurate, the sides of the dome not being straight, as shown, but slightly convex.

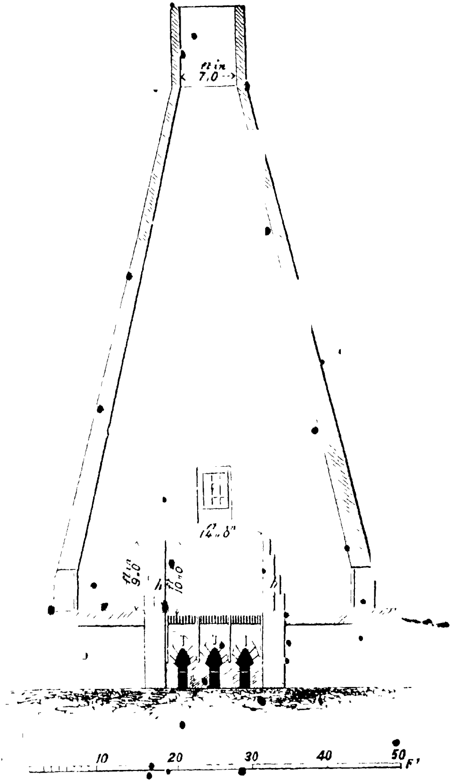


FIG 99.—Section through the centre of the kiln, in the direction of the line *cd* in Fig. 97.

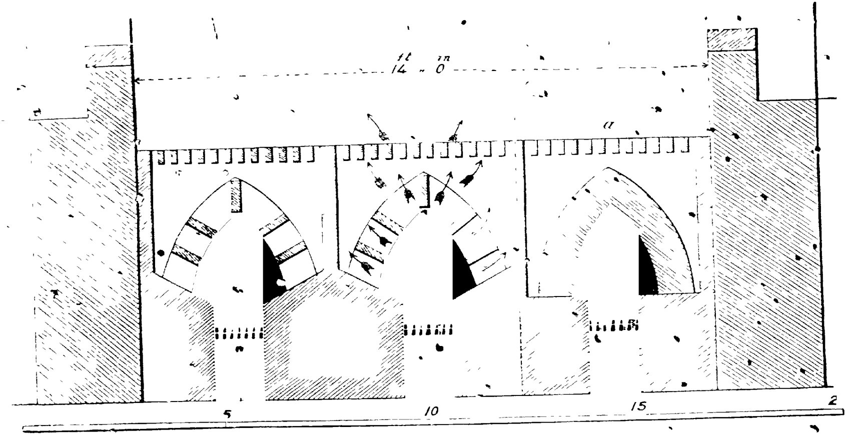


FIG. 100.—Transverse section of the furnaces. The section marked *a* is taken through the throat of the furnace, on the line marked *xy* in Fig. 101.

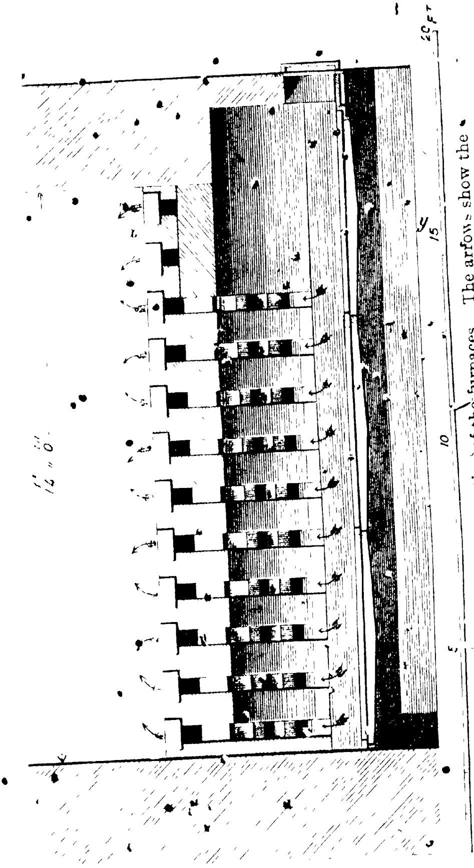


FIG. 10.—Longitudinal section of the furnaces. The arrows show the direction of the flues.

progressive tile manufacturers at the present time prefer downdraught kilns (p. 246).

### PROCESS OF MANUFACTURE.

*Clay-getting and Weathering.*—The clay used for making tiles is stronger and freer from impurities than that used for making bricks, and consequently requires more care in its treatment.

When the clay is too strong, it is mixed with sand before passing it through the pug-mill.

The weathering of the clay is performed by spreading it out in thin layers, about 2 in. thick, during the winter, and each layer is allowed to receive the benefit of at least one night's frost before the succeeding layer is placed over it. Some clays may be spread out in the summer to be scorched by the sun, which effects their weathering equally well. The greater the heat, or the sharper the frost, the thicker may be the layers, but 4 in. is the maximum thickness.

The object of the process of weathering is, to open the pores of the clay, and to separate the particles, that it may absorb water more readily in the subsequent process of mellowing and tempering.

The clay thus weathered is thrown into pits, where it is covered with water, and left for a considerable time to mellow, or ripen. With some clays this process is unnecessary.

*Tempering.*—The process of tempering is performed simply by passing the clay through the pug-mill. If the clay be very foul, that is, full of stones, it is *slung* before using, and passed a second time through the mill. It may be slung either once or twice, and pugged twice or thrice, according to the nature of the clay.

Some clays require to be crushed between rollers, or ground to powder before being pugged.

*Slinging.*—The operation of slinging is as follows: as the clay issues from the ejectment hole of the pug-mill, it is cut into lengths of about 2 ft., with a sling. These lumps are taken by the slingers and cut up into slices, not exceeding ¾ in. in thickness, during which operation most of the stones fall out, and those which remain are picked out by hand. The clay thus freed from stones is once more ground, and is then ready for the moulder. Mechanical clay cleaners (p. 173) are preferable when a large quantity of clay is used. Washed clay (p. 70) is sometimes employed.

In some districts the clay is still freed from stones by sifting, and the tempering is performed by treading; this part of the work being done by boys, who tread in a spiral track, so as to subject each portion of the mass to a uniform amount of kneading, but this is unusual.

*Moulding.*—The clay, as it issues from the mill, is cut into lumps, called *pieces*, which are stacked on a rough bench in the shed. A labourer cuts these lumps in half, each half being called a *half-piece*, and wheels these half-pieces one by one to the pantile table.

A rough-moulder, generally a boy, takes the half-piece and *squares* it up, that is, beats it up into a slab near the shape of the mould, and about 4 in. thick, from which he cuts off a thin slice, the size of a tile, and passes it to the moulder.

The moulder, having sanded his stock board, and placed his mould on the four pegs (Fig. 84), which regulate the thickness of the tile, takes the slice of clay from the rough-moulder, and puts it into the mould (Fig. 87). He then, with very wet hands, smooths the surface, cutting off the superfluous clay with his hands, in long pieces, called strippings, which are thrown to a corner of the table. This done, he strikes the surface level, with the roll (Fig. 88); and turning the tile out of the mould on the washing-off frame (Fig. 91), with very wet hands washes it into a curved shape. He then strikes it smartly with the splayer (Fig. 90), and turns it over on that implement, on which he conveys it to the block, where he deposits the tile with the convex side uppermost, and, the splayer being withdrawn, the tile is left to dry. The button end of the tile is placed inside the block.

*Thwacking.*—The tiles remain in the block until they are half dry, when they are taken out one by one, placed on the thwacking frame, and beaten with the thwacker to perfect their shape.

The wing of each tile is then trimmed with the thwacking knife, and the tiles replaced in the block still with the convex side uppermost; but this time the button end is placed outside. The tiles then remain in the block until ready for burning.

It should be observed that the tiles flatten slightly whilst in the block, and for this reason the washing-off frame is made a little more convex than the thwacking frame, which corresponds to the permanent form of the tile.

*Setting and Burning.*—In setting the kiln, a course of vitrified bricks is laid at the bottom, herring-bone fashion, the bricks being placed 1½ in. apart. On this foundation the tiles are stacked as closely as they will lie, in an upright position, one course above another. As the body of the kiln is filled, the hatchways are bricked up with old bricks, and when the kiln is topped, they are plastered over with loam or clay. The top is then covered with one course of unburned tiles, placed flat, and lastly, upon these a course of old pantiles is loosely laid. This only applies to kilns of the type shown in Figs. 96 to 101; the tiles set in downdraught kilns require no "topping" or covering of clay. If the tiles will not stand high stacking, they may be placed in "cupboards" made of fireclay slabs, so that these take the weight off the tiles (p. 244).

The fires are usually lighted on Monday morning, and are not put out until Saturday evening. Owing to their thinness and tendency to twist, tiles require much care and skill in burning, so that the temperature and time of heating will vary with different clays.

The fuel used is coal, and the quantity consumed at each burning is about eight tons. This, however, varies with the clay and kiln used.

## COST OF MANUFACTURE.

As the manufacture of tiles is carried on under cover, the establishment of a large tile-work involves a considerable amount of capital.

The cost of making pantiles is about as follows, per 1000 tiles:—

| | £ | s. | d. |
|---|---|---|---|
| Clay—this is usually included in the rent, but, if purchased separately, may be taken at 2*s.* 6*d.* per yard cube—2¼ yards cube make 1000 pantiles | 0 | 5 | 6 |
| Weathering clay | 0 | 3 | 0 |
| Mellowing ditto, and pugging once | 0 | 4 | 0 |
| If slung and pugged a second time, add | 0 | 2 | 0 |
| Moulding, including all labour in fetching clay from mill, moulding, washing, blocking, thwacking, and blocking second time | 0 | 10 | 0 |
| Setting and drawing kiln | 0 | 3 | 0 |
| Burning | 0 | 12 | 6 |
| Cost of making | 2 | 0 | 0 |

By the use of power-driven machinery for crushing and pugging the clay and avoiding the necessity of mellowing it in pits the cost may be reduced by about 6*s.* By the use of downdraught kilns or of continuous ones the loss of burning may also be greatly reduced. Owing to their shape, pantiles must, however, cost more to make than do plain tiles

*Hip and valley tiles* are made in a similar manner to pantiles, but on blocks of a different shape. Some makers prefer to use plaster moulds for these tiles.

## CHAPTER XIV

### THE MANUFACTURE OF PLAIN TILES

THE methods used for manufacturing plain tiles vary greatly in different districts, and as these kinds of tiles adapt themselves more readily to production by machinery, there are still wider variations than in the manufacture of pantiles.

Where the clay is of such a nature that it does not need grinding between rollers or other treatment of a mechanical nature, the method described in the following pages may be regarded as typical. With the advantages to be obtained from the use of mechanically driven pug-mills, however, the use of more modern methods of preparing the clay has increased. These methods—which vary in different localities on account of variations in the material used—are practically the same as those used for preparing clay for brickmaking by machinery (Chap. VIII.). The reader desiring further details—which are beyond the purpose of the present volume—should consult "Roofing Tile Manufacture," by E. L. Raes (see Appendix).

*Weathering and Tempering.*—The material is dug and spread out to weather; the length of time depends upon the quality of the air: a hot, dry summer's day will do good service to some clays, and three or four such days would then enable the makers to collect a thin surface in a workable condition. Frosty weather, provided it be dry, is preferred; but wet, and alternations of wet and dry, retard the process of weathering some Midland marls. During a hot, dry season, some of these Midland marls can be dug, weathered, and made in one month, but some clays require a much longer exposure.

The weathered material is next mixed with a quantity of water and placed in the pug-mill. About 1 cubic yard per hour is ground by one horse.

The pug-mill (Fig. 82) consists of a wooden tub slightly tapered, the larger end being uppermost; it is circular and about 6 ft. high and 3 ft. diameter at the top or larger end, in which a cast-iron spindle revolves, carrying a series of flat steel arms, arranged so as to form by rotation a spiral or worm-like motion upon the clay, which is thereby pressed from a larger to a less diameter of the tub in which the clay is confined, and ultimately comes oozing out of an aperture at the bottom: this operation kneads the clay, and mixes it, giving it great cohesive power.

As pointed out in previous chapters, mechanically driven pug-mills of a more powerful type are now preferred. This clay or prepared marl, being now ready to make the tiles, is wheeled away to the stock kept under cover for that purpose.

The moulding of roofing tiles varies from that of bricks principally in the clay being stiffer, and in some cases coal-dust instead of sand is thrown in the mould each time it is filled. Some moulders prefer sand when a bright colour is desired.

*Moulding.*—The mould is 12 in. by 7¾ in. and ⅝ in. thick, made of oak plated with iron. It resembles Fig. 87. The moulder at his bench (Fig. 102) takes up a lump of clay, and works it by hand into an oblong square, somewhat less than the mould, say 11 in. by 7 in. or thereabout; the mould is placed upon the bench, and fine coal-dust or sand thrown into it; the man then takes up the lump of clay in the right position for the mould, and throws it into it with considerable force; then, with a steel wire strained upon a wooden bow, cuts off the surplus clay level with the mould, removes the lump, and finishes moulding the clay left in the mould by adding a little clay if it be wanted, and smooths it over with a wooden tool. By his side upon the bench he has two thin boards about the size of the moulded tile; their surfaces are dusted over with coal-dust or sand. Upon one of these he places the moulded tile, turning it out of the mould, and he repeats the process of moulding at the rate of from 1300 to 1500 per day, adding more clay to his lump about every six tiles moulded, and in quantity about as much as the six tiles moulded.

*Drying.*—The attendant boy carries away two tiles at each time to the floor; he takes up one on the board, and by the thick part of the hand presses up the two projections at right angles with the face of the tile, and then places board and tile on his head, and takes up a second and operates upon this in like manner as he walks to the floor, where he lays the two tiles, carrying the boards back to the moulding bench; and then repeats his operations.

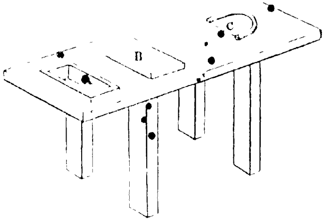


FIG. 102.—Bench for moulding tiles.
A. Coal-dust or sand box, 14 in. by 8 in.
B. Moulding board, 14 in. by 10 in.
C. The bow for cutting.

The tiles remain on this floor (which may be out of doors in fine weather) for about four hours; they are then collected and placed close together, the nib end changed alternately to allow of their resting close and square; in this state they are walled up in a dry but not hot situation, and so remain for a day or two: this is done to toughen them.

*The Set.*—The next process is to give them a curved form, sometimes termed the "set," which is done on a three-legged stool, called a horse (Figs. 103 and 104), the top of which is a little larger than the tile, and is curved one way to about a 10-feet radius. With the horse is used a wooden block, curved to correspond with the surface of the horse. These implements are used as follows: six tiles are taken as last placed and put on this horse; the man lifts up the wooden block and gives them three sharp blows with it; they are then carried away and placed in an ingeniously built wall (Fig. 105), made of the tiles to be dried, to complete the drying process, after which they are carried to the oven, twelve at each time, with the edges of the tiles against the breast of the carrier. Where the tiles cannot be stacked in the manner shown in Fig. 105, they may be laid on wooden frames, or pallets, the latter being piled one above the other like a series of shelves.

*Firing.*—Firing tiles requires much more care than firing bricks, as roof tiles are very thin and liable to twist.

Small circular kilns, either up or downdraught, are usually employed. On the bottom of the kiln are first placed 2000 bricks, as shown in Fig. 106, and upon these are placed 7000 tiles, forming a square, the spaces between the tiles and the curved side of the kiln being filled up with bricks, as shown in Fig. 107. The tiles are placed edgewise, in parcels of twelve, changing their direction for each parcel of twelve.

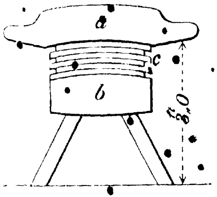


FIG. 103.—Tile block and horse.
a. The block. b. The horse. c. Tiles.

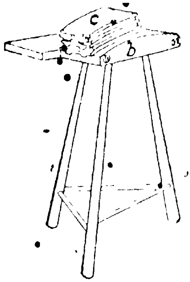


FIG. 104.—Another form of horse.
b. The horse. c. The tiles.

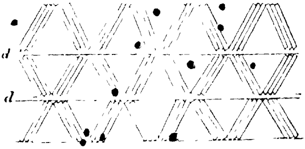


FIG. 105.—Tiles as placed during the last drying.
d, d, Laths, two to each course.

The eight rows of twelve bricks in each, as seen in Fig. 106, cover a space left in continuation of flues from the eight fire-holes. The bricks in the first seven courses are so placed as to leave a flue of an average width of four inches. The dotted lines show the position of the fire-holes.

Above them (as shown in Fig. 107) the tiles are placed in bungs of twelve, and laid alternately cross and lengthwise, the nibs space them off, and support them in a vertical position. Each side of the square is made up with bricks, as shown on the plan.

From this description, and a reference to the illustrations, it will be seen that the goods placed in the kiln are in each case so placed as to allow the diffusion of heat between them; and as the uniformity of heat is the desideratum in firing both bricks and tiles, the circular oven is found to answer better than any other at present in use, though rectangular downdraught kilns are almost if not quite as good.

Owing to the difficulty of preventing warping, it is becoming increasingly common to set tiles in "cupboards" or "boxes" made of fireclay slabs. Each box holds twelve tiles set on edge, and the slabs bear the weight of the superimposed goods. Two of them are set on their edges (to form the sides of a cupboard) and a third is laid on top of them. The side-slabs must be so placed that each supports the end of two horizontal ones. After one row of cupboards is built, a second is built above it, the vertical slabs being placed one above the other until the kiln is filled to a convenient height. It is not wise to fill a domed kiln completely, as a portion of the space in the dome is

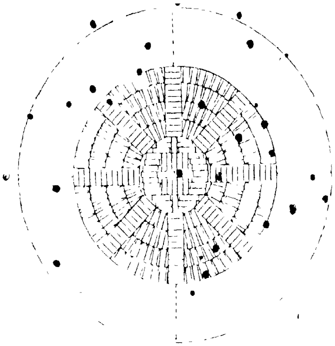


FIG. 106.—Plan of oven, as seen when eight courses of bricks are placed edgewise.

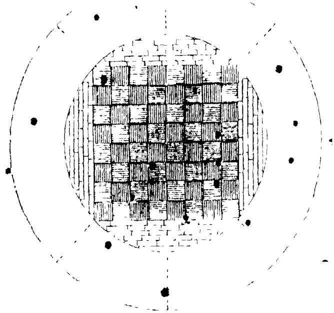


FIG. 107.—Plan of oven, as seen when the first course of tiles are placed upon the bricks, as seen in Fig. 106.

best left empty to act as a combustion and heat distribution chamber.

Plain tiles made of some clays, which have little tendency to twist, may be set flat in piles about 3 ft. or 4 ft. high.

Interlocking tiles must usually be set in cupboards, owing to their shape and inability to "pack" well.

Setting tiles require great skill, as an incompetent or careless setter may ruin a firm employing him.

It is desirable to have a wall round the outside of the kiln about 6 ft. high, and at a distance therefrom to allow the fireman space to attend his fires conveniently; this wall is dry built generally with imperfect bricks, and its use is to avoid one fire being urged more than another by the set of the wind, which duty it performs tolerably well.

When the kiln is full, the clammins (doorway) is made up with bricks daubed over with clay sweepings or loam; then the fires are kindled, and are kept slowly burning for the first 5 hours, after which they are progressively increased for the next 33, making 38 hours for hard-fired (blue) tiles; four tons of coal being consumed in the firing. These figures vary with the clay and size of kiln. The temperature is determined by the sight of the fireman directed to the mouths of the kiln. When the "finishing heat" is obtained, and before the fires burn hollow, the mouths are stopped up with ashes to prevent currents of cold air passing through the kiln, which is then suffered to cool gradually (p. 206).

*The Downdraught Kiln* is largely used for burning tiles and bricks, as it is more easily regulated, and is more economical than an updraught kiln. It may be circular or rectangular in plan, the former being the more popular. The fireplaces (*f*), usually 8 or 10 in number, are placed in the walls of the kiln (Fig. 108), and the heat rises through the openings formed at the top of the bag-walls (*b*). The flames and hot gases strike against the dome-shaped roof and descend towards the floor of the kiln, heating the goods with which they come in contact. Finally, they pass to the centre of the floor (*p*) and out through the central well (*w*) to the chimney flue (*c*).

The descending gases scatter themselves very completely through the goods, with the result that it is not difficult to obtain a sufficiently even temperature throughout the kiln, though the goods in the upper parts are liable to be more heated than those nearer the well (*w*)

Some firms prefer to use downdraught kilns with the chimney running up through the interior instead of externally, but the disadvantages in setting cause this type of kiln to be far from economical.

The internal height of the kiln and the bag walls (*b*) are somewhat lower when burning tiles than for brick-kilns. The object of an internal chimney is to produce a good draught at the commencement of the firing, as kilns with an external chimney are sometimes troublesome in this respect.

Many arrangements have been devised to cause the gases to pass through flues placed beneath the kiln floor with a view to heating it uniformly. Solid-floor kilns are usually satisfactory on dry sites, unless the kilns are very large, but they tend to slightly underfire goods placed on the floor. When a flued or "feathered" floor is used the temperature of the floor

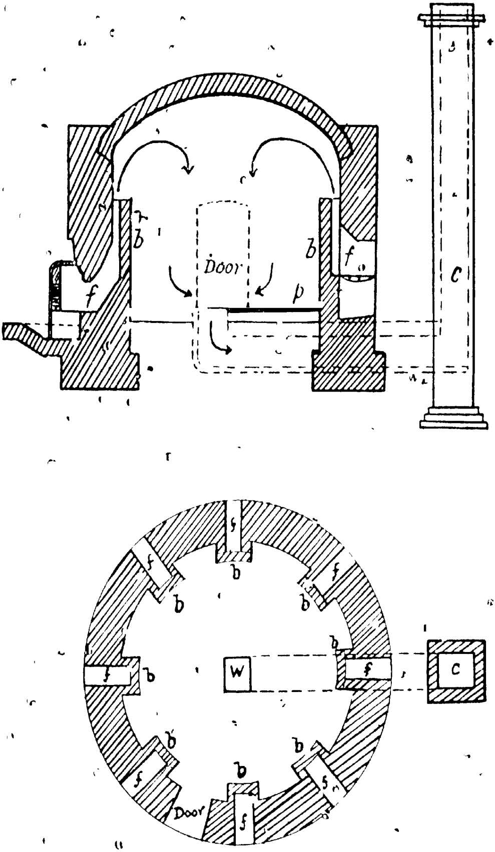


FIG. 108.—Section and plan of downdraught kiln.

is higher and the heat is better distributed. In damp sites the use of a floor of this kind reduces or even prevents the troubles due to damp rising from the ground into the kiln. Illustrations of kilns with flues under the floor are given in "Modern Brickmaking," "The Manufacture of Roofing Tiles," and other larger treatises (see Appendix).

*Continuous kilns* are much used on the Continent for roofing tiles. The chambers are somewhat narrower than those used for bricks, but apart from this most of the continuous kilns used for the latter purpose may be employed in burning tiles. As stated in a previous chapter, continuous kilns require only one-third to one-half the fuel needed by intermittent kilns, but for satisfactory work they require a larger output of tiles than is customary in this country.

Although it is possible to obtain satisfactory results with the use of great skill, it is not advisable to burn bricks and tiles promiscuously in the same *continuous* kiln. For single kilns see p. 214.

## CHAPTER XV

### ON THE MANUFACTURE OF ENCAUSTIC TILES

THE highly decorative pavements of the mediæval ages, principally to be found in our old ecclesiastical structures, have attracted the attention of antiquaries for many years, but their production is difficult because of the necessity of using clays of different colours that can be made to amalgamate in such a way as to contract or shrink equally during the processes of drying and firing. Until this is effected a perfect tile of several colours cannot be produced, sundry unsightly cracks appearing on the inlaid parts of the surface. It is unnecessary to speak of the present state of perfection to which these beautiful tiles have been brought, further than to observe that they are yearly becoming more appreciated, both on the score of durability and ornament; and there can scarcely be a doubt that, very soon, no ecclesiastical building, having any pretensions to architectural superiority, will be considered to be complete in its decorations without them.

For the encaustic tiles made by Messrs. Minton & Co. the clays of which the tiles are composed are obtained in the immediate neighbourhood of the works—the ordinary marl producing a good buff colour when fired; another kind a warm red; black is produced by staining with manganese; blue with cobalt, etc. To some clays there is a slight addition of Cornwall stone, felspar, flint, etc. The whole are subjected to a variety of washings and purifications—the clay intended for the surface, especially—and passed through fine lawn sieves in a liquid, or "slip," state, as it is technically termed. In this state it is conveyed to the slip-kiln* and "boiled," until it is in a plastic state, and fit for use.

After the modeller has done his part, the pattern is cast in plaster in relief, and is then placed in a metal frame of the size required; but it should be stated that to produce the ordinary 6 in. square tile, it is modelled $6\frac{3}{8}$ in., to allow for shrinkage or contraction, which takes place during drying and firing. The maker then commences his operations. A piece of the fine clay for the surface is flattened out to about a quarter of an inch thick, somewhat after the manner of preparing a pie crust, and this is thrown on to and pressed upon the plaster pattern, and receives, of course, a correct indentation, or outline of the design. The metal frame containing the plaster mould is divided horizontally, and after the surface is put in, the upper part of the frame is screwed on, and the maker fills up with clay of a somewhat coarser description, to form the tile of the requisite thickness. The tile is then put under a screw press (Fig. 65) to impart the proper degree of solidity. Sometimes the clay is stamped in a press to the desired shape, with the use of steel instead of plaster moulds.

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* The *slip-kiln* is a stone trough bottomed with fire tiles, under which runs a furnace flue. It is used in the manufacture of pottery for evaporating the excess of water in the *slip*, or liquid mixture of clay and ground flints, which is thus brought into the state of paste.

So far the tile is of but one colour; next comes the task of giving the different colours required. Suppose a tile be required of three colours—red, blue, and buff, and that the surface piece already put in is of a buff colour. The maker provides himself with vessels of a suitable kind, containing the one the blue, the other the red colour, in a "slip" state, and these he pours into those parts of the indented surface that the drawing or finished tile before him tells him to be correct. These slips cover the surface entirely, and there is now not the slightest appearance of any pattern or design. After remaining in this state for three days, until the water has evaporated for the most part, the process of scraping or plaining the surface commences: this is an operation requiring care, though easily effected by experienced hands. The pattern then makes its appearance, but the colours are scarcely distinguishable from one another.

The tile is then finished as far as the maker is concerned; and, after remaining in the drying house from 14 to 21 days, according to circumstances, is conveyed to the kiln, where it is fired for about 60 hours. After being drawn it is finished, except it be that the parties ordering wish the surface glazed, a rapid and easy process, the dipper merely placing the surface in a tub of glaze and refiring the tile in a glost kiln.

Encaustic tiles may also be made out of clay dust in a manner similar to tesseræ.

Plain self-coloured tiles, such as black, red, chocolate, buff, etc., and also tesseræ, are made of the same material as encaustic tiles, only that it is dried longer in the slip kiln, passed through rollers to reduce it to a powder ("dust"), and is then finely sifted. Presses of great power (Fig. 65) are used to make these tiles. The powdered clay is swept into a die of the proper size, the screw descends, and presses the powder into a solid tile, ready for drying and firing.

*Tesseræ* are now extensively used for mosaic pavements, for which they are admirably adapted.

The mosaic pavements made by the Romans were formed of small pieces of stone or marble of various colours, bedded one by one in a layer of cement, each of the pieces being levelled with the others as the work proceeded, and on the completion of the work the unavoidable inequalities of surface were corrected by *rubbing* the whole to a plane surface.

This mode of proceeding was attended with many defects. The irregular shapes of the tesseræ caused the cement joints to be of a thickness that greatly injured the effect of the design, whilst the piecemeal way in which the work was laid rendered it very difficult to produce a level surface.

The principal difficulties that lie in the use of solid tesseræ are those arising from irregularity in the shape and size of the several pieces, as well as the great labour and expense attending the laying of such pavements piece by piece. These difficulties have been entirely overcome by the use of tesseræ, made in steel dies, by the process above described, which are perfectly uniform in size, and fit closely together, with an almost imperceptible joint.

The "dry process" (p. 192) is used: the clay being first purified by washing. The slip is then dried upon a slip-kiln (p. 250), ground to a fine powder, and in that state subjected to heavy pressure in strong metal moulds: by this means the clay is reduced to one-third of its original thickness, but retains sufficient moisture to give it cohesion. The articles thus made can be handled at once, and carried direct to the kiln. They are burned in saggers in a similar manner to pottery.

This method, invented by Prosser, offers great advantages for the making of ornamental pieces for cornices, bas-reliefs, floor-tiles, tesselated pavements, etc., on account of the great accuracy in shape obtainable in conjunction with a very low shrinkage.

The mode in which the tesseræ are used is precisely the reverse of the Roman process, and is as follows :—a coloured design of the intended mosaic having been drawn to scale, after the fashion of a Berlin wool pattern, the pattern is set out full size on a cement floor, perfectly smooth and level, and on this floor the tesseræ are placed close together, the workmen being guided in the arrangement of the colours by the small drawing.

The pieces are then joined together by a layer of cement applied to the upper surface, and in this way they are formed into slabs of convenient size, which, when hard, are ready for use, and can be laid with as much ease as ordinary flagstones. It will at once be understood, that the side of the slabs which is next the floor during the process of manufacture forms the upper side of the finished pavement, the pattern appearing reversed during its formation.

## CHAPTER XVI

### THE MANUFACTURE OF LAND DRAIN TILES AND PIPES

THE manufacture of draining tiles and pipes (Figs. 80, 109, and 110) is one which daily assumes greater importance on account of the attention bestowed on agriculture, and the growing appreciation of the importance of thorough drainage. Any discussion on the best of forms of draining tiles, or the most advantageous methods of using them, would, however, be out of place in this volume. The manufacture is exceedingly simple, and as regards the preparation of the clay, and the processes of drying and burning, is precisely similar to the other branches of tile-making. The moulding is entirely done by machinery, usually of a portable character except where glazed sewerage pipes are concerned.

Bricks, paving tiles, and roofing tiles, are little required, and seldom manufactured, except in the neighbourhood of towns or of large villages, where the demand is likely to be sufficiently constant to warrant the erection of kilns, drying sheds, and other appurtenances of a well-mounted brickwork. If a cottage is to be rebuilt, a barn tiled, or it may be once in twenty or thirty years a new farmsteading erected in a rural district, it is generally cheaper to incur the expense of carting a few thousand bricks or tiles than to erect the plant necessary for making these articles on the spot. But with land drain pipes the case is reversed. They are most wanted

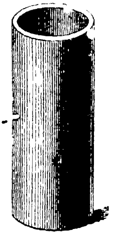

FIG. 109.—Plain drain pipe.

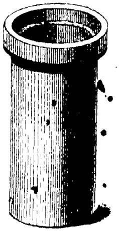

FIG. 110.—Socketed drain pipe.

precisely in situations where a brickyard would be an unprofitable speculation, viz. in the open country, and often in places where the cost of carriage from the nearest brick-yard would virtually amount to a prohibition in their use, if they cannot be made on the spot, and that at a cheap rate. What is wanted, therefore, is a good and cheap method of making drain tiles without much plant, and without erecting an expensive kiln, as the works will not be required after sufficient tiles have been made to supply the immediate neighbourhood, and therefore it would not be worth while to incur the expense of permanent erections. The making of drain tiles as a *home manufacture* is, therefore, a subject which has much engaged the attention of agriculturists at different times, and the employment of a very simple and effective kiln erected by Mr. Law Hodges and described in the *Journal of the Royal Agricultural Society* (vol. v., part 2) provides a simple means of making land drain-pipes in places otherwise difficult of access.

The material must be prepared in the form of a plastic paste by one of the methods described in an earlier chapter. This paste is then placed in a pipe-press (Fig. 111) and expressed through a die in the form of a pipe. This is then cut off into lengths by means of a pair of wires in a cutting frame in a similar manner to wire-cut bricks.

Where a wire-cut brick machine is available, it may be used to produce drain pipes, as dies for this purpose can be obtained from the machinery makers. A small separate machine is, however, more convenient.

For sewerage pipes special pipe presses are used, but the manufacture of salt glazed pipes of this character forms an entirely separate branch of the clayworking industries, and is of too specialized a nature to be described here.

As the pipes are produced they are taken away on a wooden roller placed inside them, and are placed on their ends on a floor to dry. Very narrow pipes may be dried in a horizontal position, but a vertical one is preferable where possible.

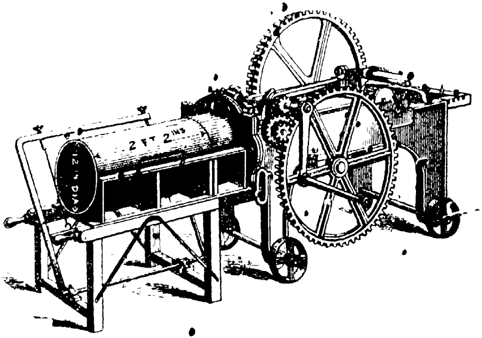

FIG. 111.—Drain-pipe machine.

Drain tiles, in so far as they are distinguished from pipes, may usually be made in the same manner, but they are open at the top or bottom, and so are more likely to twist in drying (see Fig. 80).

The pipes must be stored under cover until dry, after which they are stacked in the kiln on their ends. The shed used for drying them may, if necessary, be constructed of hurdles, these being pitched firmly in the ground in two parallel straight lines, 7 ft. apart,

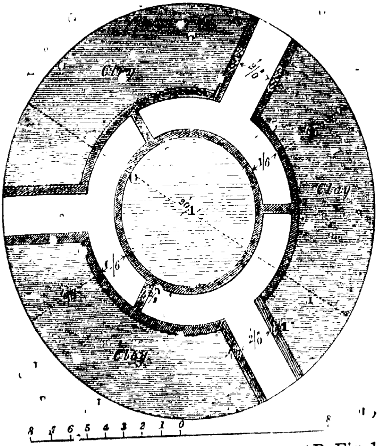

FIG. 112.—Plan of drain-pipe kiln at AB, Fig. 114.

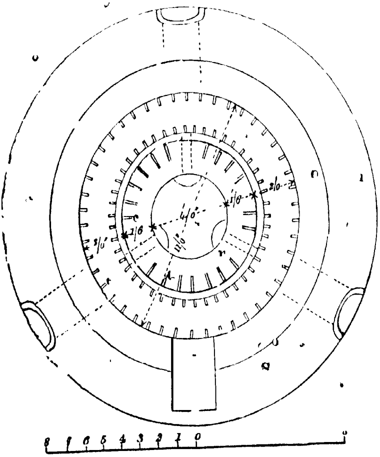

FIG. 113.—Plan of top of drain-pipe kiln.

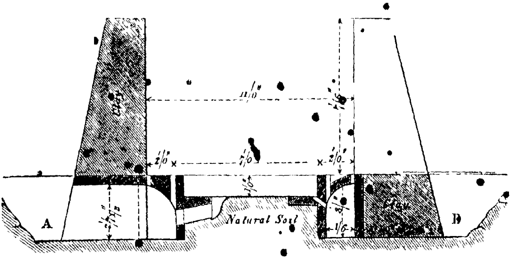

FIG. 114.—Drain-pipe kiln. Section of kiln.

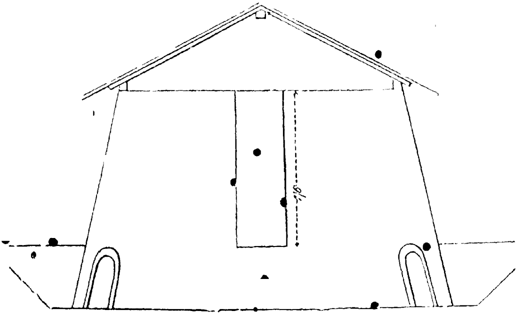

FIG. 115.—Kiln for land drain-pipes. Elevation.

to form the sides of the sheds, and the roof will be formed of hurdles placed endways and tied together at the top, as well as to the upper slit of the hurdle, with strong tarred twine, forming the ridge of the roof exactly over the middle of the shed. They must then be lightly thatched with straw or heath, and the sharpness of this roof will effectually protect the tiles from rain. Two of these sheds, each 110 ft. long, will keep one of the kilns hereafter described in full work. For large outputs a more permanent building is preferable.

These sheds should be so built as to have one end close to the pug-mill and the clay-heap, only leaving just room for the horse to work the mill, and the other end near the kiln. Attention to this matter saves future labour, and therefore money.

The pipes may be burned in almost any type of brick or tile kiln, but where only land pipes are made a temporary kiln built of clay and earth instead of bricks may be used. The form of this kiln is circular, 11 ft. in diameter, and 7 ft. high. It is wholly built of damp earth, rammed firmly together, and plastered inside and out with loam. The earth to form the walls is dug out round the base, leaving a circular trench about 4 ft. wide and as many deep, into which the fire-holes of the kiln open. If wood be the fuel used three fire-holes are sufficient; if coal, four will be needed. About 1200 common bricks are wanted to build these fire-holes and flues; if coal is used, rather fewer bricks will be wanted, but then some iron bars are necessary—six bars to each fire-hole.

The earthen walls are 4 ft. thick at the floor of the kiln, are 7 ft. high, and tapering to the thickness of 2 ft. at the top; this will determine the slope of the exterior face of the kiln. The inside of the wall is carried up perpendicularly, and a loam plastering inside becomes, after the first burning, like a brick wall. The kiln may be safely erected in March, or whenever the danger of injury from frost is over. After the summer use of it, it must be protected by faggots or litter against the wet and the frost of winter.

A kiln of these dimensions will contain—

| | | | |
|---|---|---|---|
| 47,000 | 1-in. bore pipe tiles. | | |
| 32,500 | 1¼ | ,, | ,, |
| 20,000 | 1¾ | ,, | ,, |
| 12,000 | 2 | ,, | ,, |

and the last-mentioned size will hold the same number of the inch pipes inside of them, making therefore 24,000 of both sizes. In good weather this kiln can be filled, burned, and discharged once every fortnight; and fifteen kilns may be obtained in a good season, producing—

| | | | | |
|---|---|---|---|---|
| | 705,000 | 1-in. pipe tiles. | | |
| Or | 487,500 | 1¼ | ,, | ,, |
| Or | 300,000 | 1¾ | ,, | ,, |

and so on in proportion for other sizes.

It requires about 2½ tons of good coals to burn the above kiln full of pipes. 3000 brush faggots will effect the same purpose. Some clays require more burning than others; the stronger the clay the less fuel required.

*Cost.*—The whole of the plant and building, if erected of hurdles, need not cost more than £50, thus—

| | £ | s. | d. |
|---|---|---|---|
| Second-hand pug-mill | 10 | 0 | 0 |
| Second-hand pipe machine | 15 | 0 | 0 |
| Cost of erecting kiln | 15 | 0 | 0 |
| Cost of sheds excluding hurdles | 10 | 0 | 0 |
| | 50 | 0 | 0 |

The cost of production will vary from 5s. per 1000 for 1-in. pipes to 12s. per 1000 for 3-in. pipes, all 1 ft. or slightly over in length.

Where other clay goods are manufactured, the land pipes are, naturally, burned in one of the existing kilns, being placed on their ends one above another until the kiln is filled.

# CHAPTER XVII

## HOLLOW BRICKS AND BLOCKS

HOLLOW blocks are made in pipe machines or by the wire-cut process (p. 184). They are becoming increasingly popular on account of their lightness and sound proofness. The clay is made into a stiff paste by one of the methods previously described, and is then put into an expression press fitted with a die or mouthpiece, through which the block or brick extrudes in the form of a long column which is afterwards cut by wires into blocks of convenient length. The die or mouthpiece is provided with one or more cores which produce the hollow parts of the blocks, and care is needed to ensure that the cores are properly adjusted. Further details together with illustrations of the plant used will be found in "Modern Brickmaking" (p. 266).

The idea of tubular or hollow bricks is not new, for such articles were used by the Romans in large vaultings, where lightness of construction was required, and they are said to be in common use in Tunis at the present time. The size of the bricks and blocks varies greatly, many are 12 in. long, and three courses rise 1 ft. in height. In passing them through the machine, or in the process of drying, the bricks can be splayed at the ends for gables, or marked for closures, and broken off as required in use, or they may be perforated for the purpose of ventilation. If nicked with a sharp-pointed hammer, they will break off at any desired line; and the angles may be taken off with a trowel as in the common brick. The bricks for the quoins and jambs

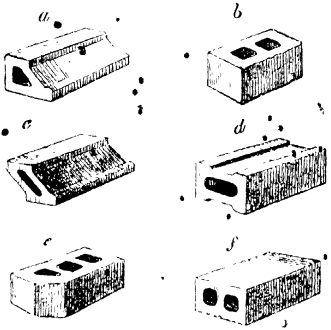

FIG. 116.—Hollow bricks.

may be made solid or perforated, and with perpendicular holes, either circular, square, or octagonal those in the quoins may be so arranged as to serve

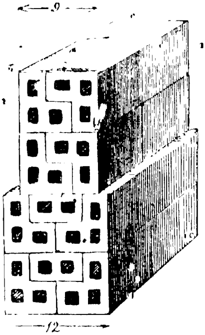

FIG. 117.—Hollow wall blocks.

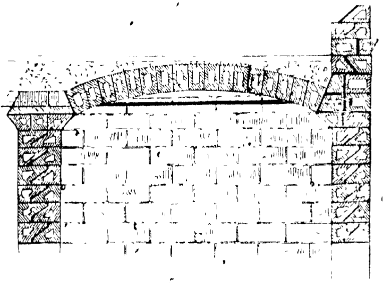

FIG. 118.—Hollow floor and walling.

for ventilating shafts. Hollow bricks, from their mode of manufacture, are more compressed than common bricks, require less drying, and are better burned with less fuel.

The following figures represent some of the forms of hollow bricks in common use. *a*, Fig. 116, is an *external* brick, 11¾ in. long, which with the *quoin* brick *e* and the *jamb* brick *b*, are sufficient for building 9-in. walls, *c* is 10¼ in. long, with one splayed corner for forming external angles, reveals, and jambs of doors and windows either square or splayed. The *internal jamb* and *chimney* brick, *d*, is 8¾ in. long; *c* is an internal brick, adapted to any thickness of wall beyond 9 in.; *d* is for 5¾-in. partitions, or internal walls, and arch bricks, and is used for floor and roof arches of 7 to 10 ft. span. *f* is used for the same purpose, with a webb to give extra strength, and to adapt them for using on edges in partitions, 3¾ in. thick to rise in 6-in. courses.

Fig. 117 represents a specimen of hollow brickwork in 6-in. courses, with square rebated joints for extra strength. These bricks are adapted to the lining of flint or concrete walls. Fig. 118 is a section of an arch and partition. The external springers may be of cast iron, connected by wrought-iron tie rods.

Of recent years many forms of hollow blocks have been devised, each firm engaged in this business employing blocks of its own designs.

There are many advantages in favour of bonded hollow bricks over ordinary bricks, in addition to a considerable diminution in the cost of carriage or transport, and of 25 per cent. on the mortar and the labour.

For many large buildings decorated with glazed work they are invaluable (see *Frontispiece*), and for interior work they form excellent fireproof partitions and supports for concrete floors.

# APPENDIX.

## SHORT LIST OF BOOKS OF VALUE TO BRICK AND TILE MAKERS.

| Author | Title. | Publisher. | Price. | |
|---|---|---|---|---|
| Ansell, H. | "Glazed Bricks" | The Clayworker Press, London | 7s | 6d. |
| Bourry, E. | "Treatise on Ceramic Industries" | Scott, Greenwood & Son, London | 12s. | 6d. |
| Brown, A. E. | "Brick Drying" | The Clayworker Press, London | 2s. | 6d. |
| Brown, A. E. | "Hand Brickmaking" | The Clayworker Press, London | 2s. | 6d. |
| Furnival, W. | "Leadless Glazes for Tiles" | W. J. Furnival, Stone, Staffs. | | * |
| Raes, E. L. | "Roofing Tile Manufacture" | Maclaren & Sons, Ltd., London | 2s. | 6d. |
| Searle, A. B. | "British Clays" | C. Griffin & Co., Ltd., London | — | |
| Searle, A. B. | "Clayworker's Handbook" | C. Griffin & Co., Ltd., London | 6s. | 0d. |
| Searle, A. B. | "Modern Brickmaking" | Scott, Greenwood & Son, London | 12s. | 6d. |
| Worcester, W. G. | "Bulletin 11.—Roofing Tiles" | Ohio Geological Survey, U.S.A. | 4s. | 0d. |

* Published at Six Guineas, but obtainable second hand for about a sovereign.

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